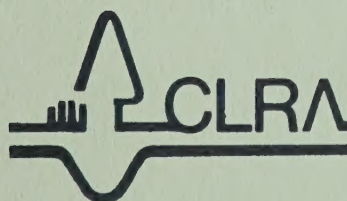
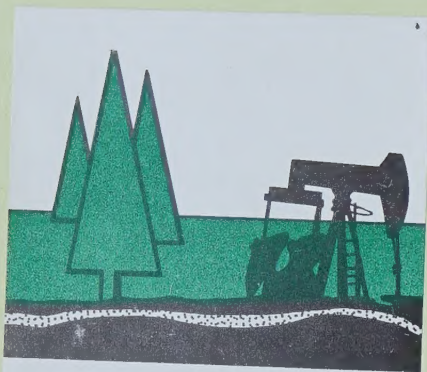


PROCEEDINGS OF THE SECOND ALBERTA RECLAMATION CONFERENCE

**February, 1983
Edmonton, Alberta**



CANADIAN LAND RECLAMATION ASSOCIATION



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Proceedings of the Second
Alberta Reclamation Conference

February 23 and 24, 1983

Convention Inn South

Edmonton, Alberta

Held in conjunction with the
20th Annual Alberta Soil Science Workshop

February 22 and 23, 1983

Sponsored by:

Alberta Chapter, Canadian Land
Reclamation Association

The Coal Association of Canada

Oil Sands Environmental Study Group

Alberta Land Conservation and
Reclamation Council

Canadian Petroleum Association



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PREFACE

The second Alberta Reclamation Conference was held in conjunction with the Alberta Soil Science Workshop. This report is a compilation of the papers presented at the reclamation portion of the conference held at the Convention Inn South in Edmonton, Alberta on February 23 and 24, 1983.

The major objective of this conference was to pull together people involved in land reclamation in Alberta and provide a forum for presentation and subsequent discussion of new techniques, ideas or results of research. The participants came from a cross-section of government, industry and university primarily from Alberta.

Sponsors of the conference were: Alberta Chapter, Canadian Land Reclamation Association, The Coal Association of Canada, Oil Sands Environmental Study Group, Alberta Land Conservation and Reclamation Council and the Canadian Petroleum Association.

Our appreciation is extended to those who attended and made the conference a success, particularly the authors, coauthors and session chairmen. Special thanks are due to the chairman of the organizing committee, Malcolm Ross (Crows Nest Resources) representing The Coal Association of Canada; to Paul Ziemkiewicz (Alberta Energy and Natural Resources) representing the Alberta Chapter Canadian Land Reclamation Association and the Alberta Land Conservation and Reclamation Council, Julia Fulford (Fording Coal) and, Dave Paton (NOVA, AN ALBERTA CORPORATION). The Oil Sands Environmental Study Group was represented by Al Fedkenheuer.

The conference was highlighted by a joint session with the Alberta Soil Science Workshop on the topic of soil reclamation. We thank John Hermans and Hank Vander Pluym (Alberta Agriculture) for their efforts with that session. Thanks are also due to Wayne Pettapiece (Agriculture Canada), Jean Crepin (Norwest Soil Research Ltd.) and Brent Paterson (Alberta Agriculture) of the Alberta Soil Science Workshop Organizing Committee for their efforts in making the conference a success.

The twenty eight papers covered a range of activities dealing with coal mining, open pit oil sands mining, government policy, pipelining and sodic soils. Should you wish more information on a paper please contact the author.

Additional copies of this publication are available from:

P.F. Ziemkiewicz,
Alberta Energy and Natural Resources,
Petroleum Plaza -- South Tower,
9915 - 108 Street,
Edmonton, Alberta T5K 2C9

Cost of the copies is \$20.00 and cheques should be made payable to: Alberta Chapter, Canadian Land Reclamation Association

A.W. Fedkenheuer,
Papers Chairman,
Alberta Reclamation
Conference.

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ALBERTA RECLAMATION CONFERENCE
Alberta Chapter, Canadian Land Reclamation Association
Edmonton, Alberta
February 23 to 24, 1983

THE ORGANIZATIONAL STRUCTURE AND ROLE OF
THE LAND CONSERVATION AND RECLAMATION COUNCIL

By
J.M. King, P. Ag.
Chairman, Land Conservation and Reclamation Council

Abstract

This paper examines the present organizational structure of the Land Conservation and Reclamation Council as well as the jurisdictions of the Council members (field staff). Also discussed is the role and legislative mandate of the council in ensuring proper reclamation for both regulated and non-regulated surface operations. The paper concludes with a brief discussion of some possible future directions for land reclamation in Alberta.

Introduction

Land Reclamation practices have improved greatly since their inception. Prior to 1963, there were no legislative requirements for reclamation other than those contained in lease or easement agreements between the operator and the landowner or in right-of-entry orders.

The Surface Reclamation Act was established in 1963 under the administration of the Department of Mines and Minerals. Under this Act, operators were required to level the leased land, remove debris and rocks, cultivate the land, control weeds and repair fences in order to leave the land in a condition that would not interfere with farming operations. The responsibility for administering the Act was transferred to the Department of Environment in 1971.

The Land Surface Conservation and Reclamation Act was established in 1973 and Part 3 of the Act was proclaimed in August, 1978. Under part 2 of this Act a number of regulations were developed (see references 1-12). The intention of the Act and Regulations is to ensure that proper land conservation as well as reclamation would be followed for any surface disturbance. The standards for reclamation were set out in the "Guidelines for Reclamation of Land in Alberta" (1977). In addition, minimum acceptable reclamation standards for public and private lands were established in 1982 and forwarded to all operators, counties and municipalities (see references 13-14).

Organizational Structure of the Land Conservation and Reclamation Council

The Land Conservation and Reclamation Council was established under Section 15 of the Land Surface Conservation and Reclamation Act. This section of the Act specified that the council was to consist of the following members:

- a) the Chairman of the Council; an employee of the Department of the Environment;
- b) two Deputy Chairmen of the Council; employees of the Department of Energy and Natural Resources;
- c) Council Members (Reclamation Officers) appointed as employees of the Department of Environment;
- d) Council Members appointed as employees of any government agency (Energy and Natural Resources) other than the Department of Environment;
- e) Local Council Members appointed by local authorities;

In accordance with the Land Conservation Regulations, there are three committees established which make their recommendations to the Chairman of the Council. These committees are as follows:

- a) the Exploration Review Committee;
- b) the Crown Mineral Disposition Review Committee; and
- c) the Development and Reclamation Review Committee.

In addition to the above three committees, there is a Reclamation Research Technical Advisory Committee which also makes its recommendations to the Chairman of the Council.

At present, the Chairman of the Council, Manager, Secretary and Chairman of the Development and Reclamation Review Committee, are located within the Department of Environment while the two Deputy Chairmen, Deputy Secretary and Chairman of the Reclamation Research Technical Advisory Committee are located within the Department of Energy and Natural Resources. The Council Members (Reclamation Officers) are situated in field offices throughout the province of Alberta. The organizational structure of the Land Conservation and Reclamation Council is outlined in Figure 1.

Jurisdictions of the Council Members

The following three kinds of field staff are designated as Council Members:

a) Reclamation Officers from the Department of Environment

The Department of Environment Reclamation officers are responsible for all regulated and non-regulated operations on private land, metis colonies, Indian Reserves, and all other Crown lands except the land which is under the administration of the Public Lands Act. They work jointly with the Reclamation Officers from the Department of Energy and Natural Resources when dealing with regulated operations on Crown Lands. For regulated and non-regulated operations on private land, Environment's Reclamation Officers work with local reclamation officers (designated as local Council Members) appointed by the local authorities.

Organizational Structure of The Land Conservation
and Reclamation Council

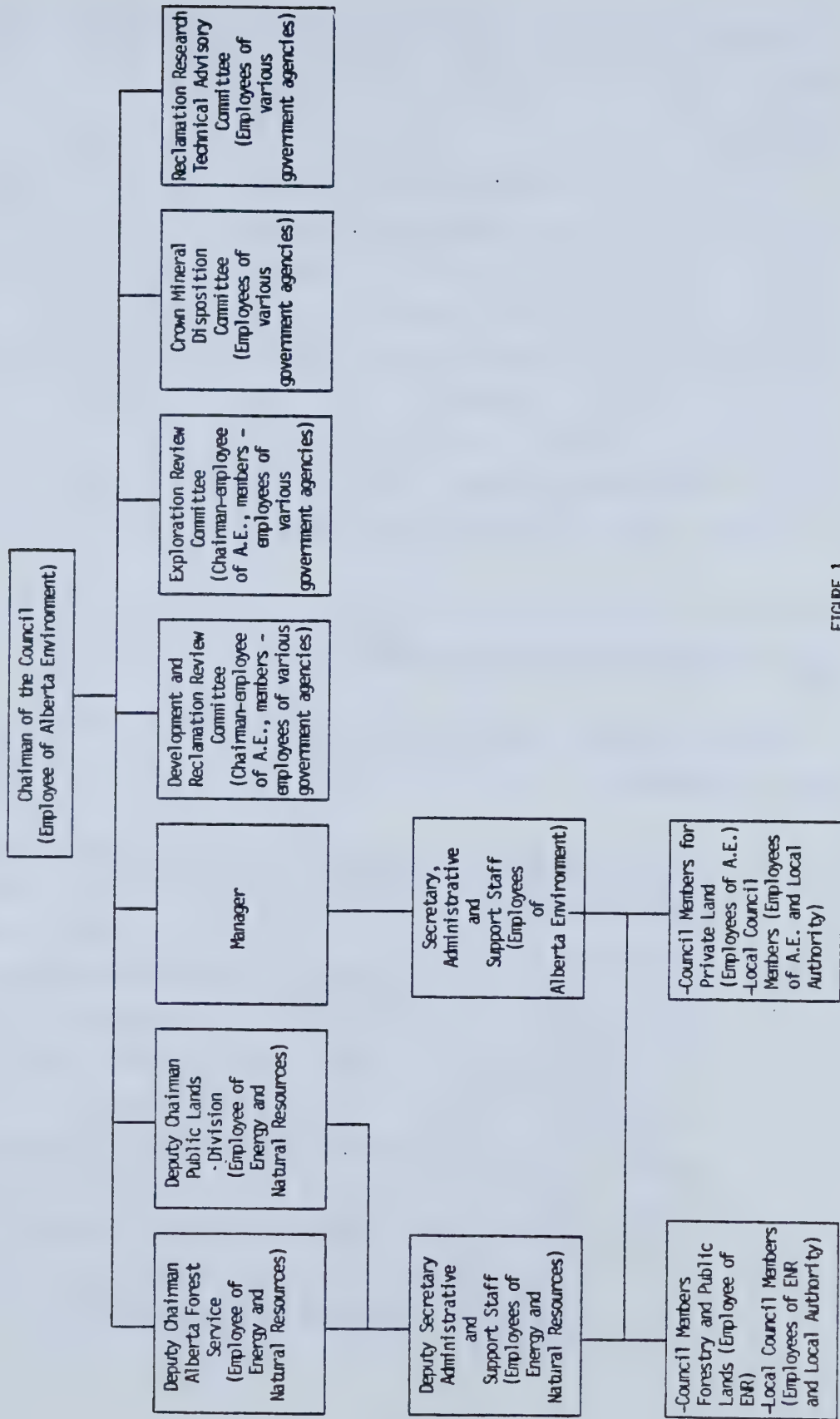


FIGURE 1

b) Reclamation Officers, (Forest Officers and Public Lands Officers) from the Department of Energy and Natural Resources

The officers from the Department of Energy and Natural Resources are alone responsible for non-regulated operations on Crown land and work jointly with the Environment Reclamation Officers on regulated operations. There are currently a number of reclamation officers who also hold the title of forest officers or Public Land Use Officers and they are employed by Energy and Natural Resources.

c) Field Staff (Local Reclamation Officers) from Local Authorities

Each local authority may appoint two or more Local Reclamation Officers. There must be a minimum of two Local Reclamation Officers appointed from each municipality. One of these local members must be present at each inquiry at which a Reclamation Order or Reclamation Certificate is to be issued. These Local Reclamation Officers act only in cases involving land in the municipality for which they are appointed.

Functions of the Various Committees

The functions of the various committees are as follows:

a) Exploration Review Committee

The Exploration Review Committee consists of various government agencies, reviews applications for exploration under the applicable Regulated Surface Operations Regulations. This committee assesses the applications with regard to the overall potential impact of the project on the environment.

b) Crown Mineral Disposition Review Committee

The Crown Mineral Disposition Review Committee consists of various government agencies, reviews applications for the purchase of crown mineral rights and assesses the potential environmental impact of the proposed mineral disposition.

c) Development and Reclamation Review Committee

The Development and Reclamation Review Committee also consists of various government agencies, deals with major coal and oil sands developments applications for Development and Reclamation approval.

d) Reclamation Research Technical Advisory Committee

The Reclamation Research Technical Advisory Committee also represent various government agencies, reviews proposals for land reclamation research and makes recommendations to the Chairman of the Council.

Regulated and Non-Regulated Surface Disturbing Operations

a) Regulated Operations:

Under Section 23 (1) of the Act, the Lieutenant Governor in Council may designate any of the numerous kinds of operations or activities as a regulated surface operation.

At present, pipelines (150 mm or more in diameter and 16 km or more in length) coal exploration and developments, oil sands exploration and developments and sand and gravel developments (over 5 acres in size) are designated as regulated surface operations. For each operation, regulations have been developed under the Act. For regulated surface disturbing operations, the proper standard of reclamation is ensured by requiring Development and Reclamation (D and R) approval prior to any surface disturbance of the land.

Major coal and oil sands developments are reviewed and coordinated by the D and R review committee recommending whether D and R approval should be granted. Coal and oil sands exploration projects are reviewed and coordinated by the Exploration Review Committee regarding D and R approval. Rest of the regulated operations (pipelines, sand and gravel and minor coal and oil sands development projects) are reviewed and coordinated solely by the Regulated Operations Branch, Land Reclamation Division, for such approval.

b) Non-Regulated Operations:

All of the remaining land surface disturbing operations are non-regulated operations except those lands used for residential and industrial purposes or agricultural operations. Under Section 35 of the Act, the Council has the authority to ensure the land is properly reclaimed by the operators of both regulated and non-regulated operations. These operations covered under the Act are:

- a) the drilling, operation or abandonment of a well;
- b) the construction, operation or abandonment of a pipeline, battery or transmission line;
- c) the opening up, operation or abandonment of a mine or quarry;
- d) the opening up, operation or abandonment of a pit or of a waste disposal site or land fill site;
- e) the conduct of exploration operations;
- f) any other operation or activity designated as a regulated operation; and

- g) the construction, operation or abandonment of a extra-territorial undertaking.

For non-regulated operations, Development and Reclamation approval is not required. However, Section 39 of the Act stipulates that, in the absence of regulations, land reclamation is to be done in a manner satisfactory to the Council. With respect to these operations, the Council uses the reclamation guidelines and minimum reclamation requirements for public and private land to ensure that adequate land reclamation is achieved (see references 13 and 14).

Security Deposits

Pursuant to the Security Deposit Ministerial Regulations, an applicant for a regulated operation is required to submit a security deposit as set out in the Regulation. These funds are held during the operation and are released when a Reclamation Certificate is issued. However, in the case of pipelines the security deposit is released upon the Reclamation Officer being satisfied that reclamation has been satisfactorily completed.

Reclamation Orders for Regulated and Non-Regulated Operations

Pursuant to Section 42, Part 3 of the Act, the Council is authorized to issue a reclamation order to a person who is not satisfactorily carrying out a non-regulated or regulated surface operation.

Reclamation Certificates for Regulated and Non-Regulated Operations

Pursuant to Section 52 and 54, Part 3 of the Act, before an operator can surrender the surface lease, he must apply for and receive a reclamation certificate from the Council.

The issuance of a Reclamation Certificate requires an inspection of the site by the government and local Reclamation Officers. The surface owner, and the company representatives may be present at the inspection if they so desire. Any indication of a problem with the land could require soil samples to be taken for analysis. The Reclamation Officers could then, depending on the results of the soil analysis issue a reclamation certificate.

Possible Future Directions for Land Reclamation in Alberta

It is essential that industry and the Council cooperate and communicate effectively to ensure that further progress in land reclamation is achieved. For example, the Council believes that there is a need for detailed soil mapping of pipeline rights-of-way conducted by qualified specialists. Meetings between the company, government agencies and the Council are thus necessary in order to explore the best use of this information and discuss mutual concerns. Industry's cooperation is requested in supplying the Council, when appropriate, with evidence of proper land reclamation, such as soil samples collected and analyzed by qualified personnel. This in turn expedites the process of obtaining a reclamation certificate from the Council.

Over the next year, the Council will be working towards reviewing the presently existing procedures of inspection, monitoring and enforcement. Important aspects of these procedures will be to maintain closer contact with landowners who are directly affected by projects, and to increase supervision by the Council's field staff during construction. By these means, it is hoped that the expectations of landowners will be met and proper reclamation will be done.

The Council is also working on developing a set of guidelines which might be described as soil inventory guidelines for pipelines. The guidelines could include such topics as: the level of detail of the survey; various methods of sampling; types of analyses to be performed; and methods of reporting the inventory. The Council will also be reviewing the Development and Reclamation application guidelines for land reclamation. These Guidelines could provide general reclamation criteria to be considered by the industry as well as explain the various steps involved in the review and approval process and the procedures of obtaining a reclamation certificate.

The Council will, in addition, continue to develop sand and gravel administrative procedures as it is the responsibility of the Council to implement the Sand and Gravel Regulations.

In conclusion, it is the aim of the Council to ensure that proper land conservation and reclamation is carried out for both regulated and non-regulated surface disturbing operations. This requires a cooperative effort between industry, the Council and other government agencies. In addition, it is the objective of the Council to achieve proper land reclamation in the most cost efficient manner. The Council will continue to welcome any input regarding possible improvements in present land reclamation procedures.

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THE ALBERTA GOVERNMENT
RECLAMATION RESEARCH PROGRAM

1 9 8 2

31 MARCH 1983

Prepared

by

P.F. Ziemkiewicz
Chairman

Reclamation Research
Technical Advisory Committee
of the
Alberta Land Conservation
and Reclamation Council

INTRODUCTION

The regulation of surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a chairman from the Department of the Environment and two deputy chairmen from the Department of Energy and Natural Resources. Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The reclamation research program was established to provide answers to the many practical questions which arise in reclamation. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund.

To assist in technical matters related to the development and administration of the research program the Council appointed the Reclamation Research Technical Advisory Committee (RRTAC). The Committee first met in March, 1978 and consists of eight members representing the Alberta Departments of Agriculture, Energy and Natural Resources, Environment and the Alberta Research Council. The Committee meets regularly to up-date research priorities, review solicited and unsolicited research proposals, arrange workshops and otherwise act as a referral and coordinating body for reclamation research.

Additional information on the Reclamation Research Program may be obtained by contacting:

Dr. P.F. Ziemkiewicz, Chairman
Reclamation Research Technical Advisory Committee
Alberta Energy and Natural Resources
9915 - 108th Street
9th Floor, Petroleum Plaza, South Tower
EDMONTON, Alberta
(427-8042)

RECLAMATION RESEARCH REPORTS

Available From: Publication Services
Queen's Printer
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EDMONTON, Alberta
T5G 2Y5 *

1. TITLE: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites
#RRTAC 80-3
AUTHOR(S): N.S.C. Cameron et al.
DESCRIPTION: This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.
2. TITLE: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation.
#RRTAC 80-4
AUTHOR(S): P.F. Ziemkiewicz, S.K. Takyi, H.F. Regier
DESCRIPTION: Experts in the Field of Forestry and Forest Soils Report on Research relevant to Forest Soil Reconstruction and discuss the most effective means of restoring forestry capability of mined lands.
3. TITLE: Manual of Plant Species Suitability for Reclamation in Alberta, 2 Vols.
#RRTAC 80-5
AUTHOR(S): L.E. Watson, R.W. Parker, P.F. Polster
DESCRIPTION: Forty-three grass, fourteen forb and thirty-four shrub and tree species are assessed in terms of their fitness for use in Reclamation. Information presented includes: Range Maps, Growth Habit, Propagation, Tolerances and Availability.
4. TITLE: 1980 Survey of Reclamation Activities in Alberta. #RRTAC 81-2
AUTHOR(S): D.G. Walker, R.L. Rothwell
DESCRIPTION: This survey is an update of the original Report conducted in 1976 on Reclamation Activities in Alberta, includes Research and Operational Reclamation, locations, personnel etc.
5. TITLE: Proceedings: Workshop on Coal Ash and Reclamation. #RRTAC 81-3
AUTHOR(S): P.F. Ziemkiewicz, R. Stein, R. Leitch, G. Lutwick
DESCRIPTION: Presents nine Technical Papers on The Chemical, Physical and Engineering Properties of Alberta Fly and Bottom Ashes, Revegetation of Ash Disposal Sites and Use of Ash as a Soil Amendment. Workshop discussions and summaries are also included.
6. TITLE: Land Surface Reclamation: An International Bibliography 2 Vols. #RRTAC 82-1
AUTHOR(S): H.P. Sims, C.B. Powter
DESCRIPTION: Literature pertinent to Reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta Computing System. The Keyword Index and Computer Access Manual comprises Vol. II
7. TITLE: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. #RRTAC 82-2
AUTHOR(S): C.B. Powter, H.P. Sims
DESCRIPTION: This Bibliography provides baseline information for persons involved in Reclamation Research or in the Preparation of Environmental Impact Assessments. Materials, up to date as of Dec. 1981 are available from the Alberta Environmental Library.
8. TITLE: Soil Reconstruction Design for Reclamation of Oil Sand Tailings.
#OESG-RRTAC 83-1
AUTHOR(S): Monenco Consultants Ltd.
DESCRIPTION: Volumes of Peat and Clay required to amend Oil Sand Solid Tailings were estimated based on existing literature. Separate soil prescriptions were made for Spruce, Jack Pine and Herbaceous cover types. The estimates form the basis of recently initiated field trials.
9. TITLE: The Alberta Government's Reclamation Research Program 1982. #RRTAC 83-2
AUTHOR(S): P.F. Ziemkiewicz
DESCRIPTION: This Report details the Reclamation Research Program indicating priorities, project status, researchers, results and expenditures.
10. TITLE: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta.
#RRTAC 83-3
AUTHOR(S): Hardy Associates (1978) Ltd.
DESCRIPTION: Available information on Pipeline Reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type construction method etc. on resulting crop production.
11. TITLE: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology, #RRTAC 83-4
AUTHOR(S): P.F. Ziemkiewicz
DESCRIPTION: Technical Papers are presented dealing with the Impacts of Mining on Mountain Watersheds, their flow characteristics and resulting water quality. Mitigative measures and Research priorities were also discussed.
12. TITLE: Woody Plant Establishment and Management for Oil Sands Mine Reclamation.
#OESG-RRTAC 83-5
AUTHOR(S): Techman Engineers Ltd.
DESCRIPTION: This is a review and analysis of information on planting stock quality, rearing, site preparation, planting and procedures necessary to ensuring survival of trees and shrubs in oil sand reclamation.

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Please make cheque payable to: "Provincial Treasurer of Alberta".

RECLAMATION IN ALBERTA

Most of Alberta's industrial activity occurs in three major biophysical regions: The Plains, where most of the Province's agricultural land is located, the Mountains and Foothills where recreation, forestry, wildlife and watershed values are predominant, and Northeast Alberta, where wildlife and forestry values exist.

Coinciding with these regions are three major disturbance types:

- 1) Plains: Coal mines operated in conjunction with electrical generating plants,
- 2) Mountains and Foothills: Metallurgical coal mines and high quality thermal coal for export, and
- 3) Northeast Alberta: Oil sand mining and extraction facilities.

While it is expected that research results will often have province-wide application, the division of the program among the three biophysical regions has proven helpful in identifying priorities and directions for the research program.

THE RESEARCH PROGRAM

Following is a summary of research projects as of March, 1983. Project titles are followed by the names of the principal investigators and their affiliation.

Upon project completion a final report is submitted. Some final reports are published intact as RRTAC Reports and released to the public. Others are held pending their inclusion in comprehensive reports. A list of available publications is included on Page ii.

I. PLAINS

Reclamation Objectives

To return crop land to pre-mining levels of productivity. Productivity is taken to include both agricultural and hydrologic capabilities.

The Problem

Plains coal seams are usually overlain by bedrocks which contain a high proportion of swelling clays. When exposed to the elements the bedrock shales and sandstones break down into a material that is sticky when wet and very hard when dry. This severely hinders plant growth and agricultural operations. Above the bedrock lie glacial deposits which are usually free of the most adverse properties of the bedrock though they lack the plant nutrients and organic matter characteristic of the overlying topsoil.

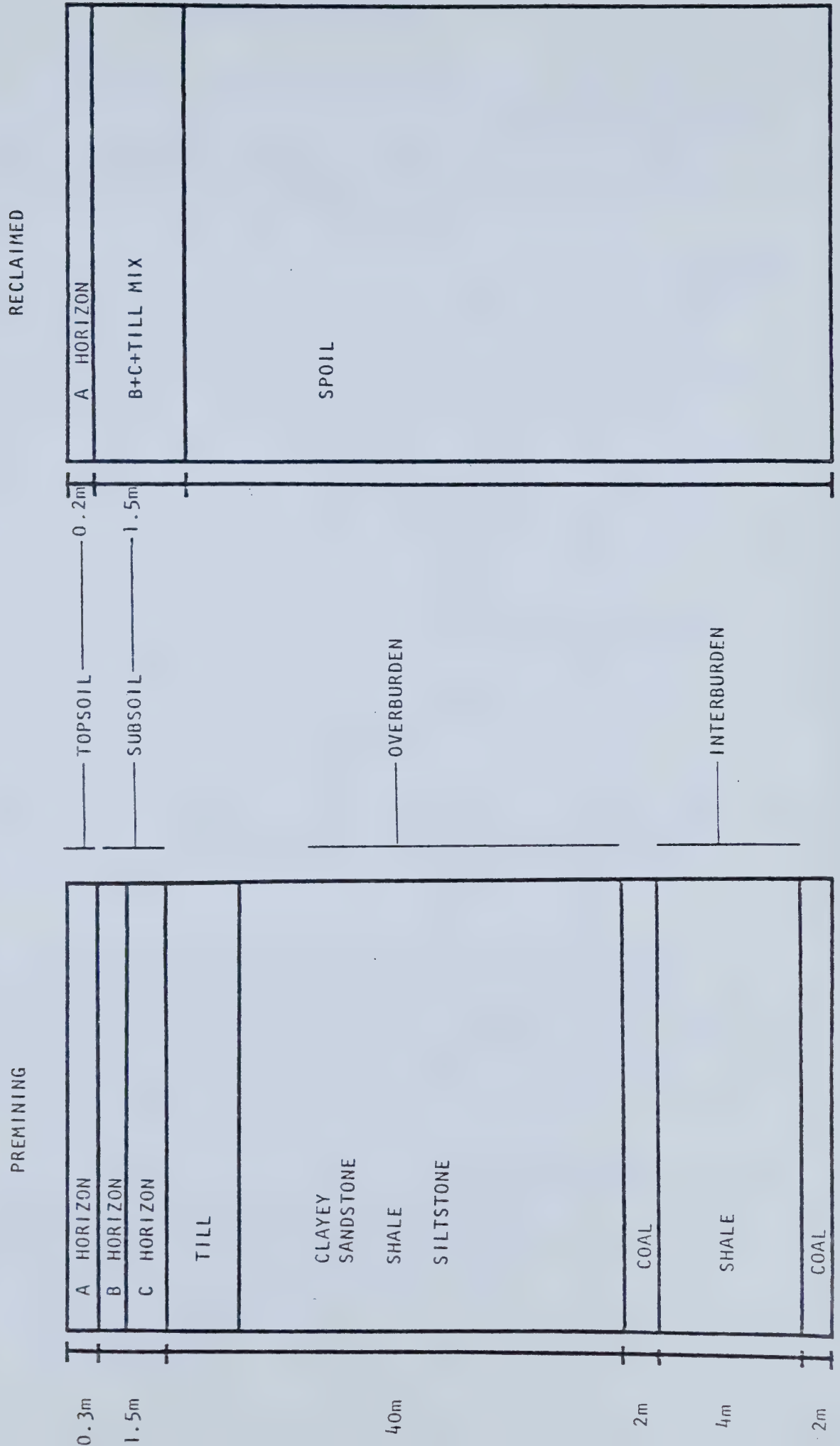
Rebuilding a soil profile is one of the major problems in cropland reclamation in Alberta. A soil must be built on levelled overburden which will be as productive as the original soil. Existing evidence indicates that placing topsoil and a buffering material over the spoil is the most efficient method for achieving this goal. However, we do not know how much capping material is needed. Also, where topsoils or subsoils are in short supply other amendments may be useful in soil building. In addition to soil reconstruction certain agricultural practices like green manuring and legume cropping may help rebuild the soil (Figure 1).

In many plains areas the coal seams are the major source of domestic water. What will happen when the coal is removed and overburden fills the mined-out pit? The behavior of the post-mining groundwater system will affect water users and could influence future agricultural potential. However, little is known about the effects of surface mining on groundwater in Alberta.

Mining on Agricultural Land

Cropland is surface mined in two major zones in Alberta: The Ardley Zone running southeast from Mayerthorpe to Red Deer and the Horseshoe Canyon Zone

FIGURE 1 — GENERALIZED PROFILES



which runs parallel and to the east from Barrhead through Camrose to Drumheller. The Ardley Zone is surface mined near Lake Wabamun to provide coal to the Wabamun and Sundance power plants. Two additional power plants, Keephills and Genessee are presently under construction and will extend mining southward to the town of Genessee. The Horseshoe Canyon Zone is mined on either side of the Battle River between Forestburg and Halkirk. These mines supply the Battle River Generating Station. Another power plant and mine are being developed to the south at Sheerness (Figure 2).

Approach

Mining in the Ardley and Horseshoe Canyon Coal Zones involves two different sets of soils, overburden and climate. Also, soil reconstruction and groundwater cannot be studied in isolation. For example, if after mining a saline watertable re-establishes within a foot of the soil surface the topsoil, regardless of its original quality, will quickly become unsuitable for crops. So in both the Ardley and Horseshoe Canyon Zones we are identifying the best methods of reconstructing soils and at the same time we are studying what happens to the groundwater after mining.

A) RECLAMATION OF COAL MINED LAND

Plains Coal Reclamation Research Program

The Plains Coal Reclamation Research Program (PCRRP) has been designed by the Provincial Government and members of the Coal Industry to answer questions relating to groundwater and soil reconstruction in both of our Plains Coal Mining Zones. Two main projects have been established:

- 1) The Plains Soil Reconstruction Project will tell us how to rebuild agricultural soils after mining and
- 2) The Plains Hydrology and Reclamation Project will describe what happens to groundwater during mining and after reclamation and how to rebuild the landscape to maximize the agricultural potential.

By combining the results of these experiments we will develop a picture of how mined landscapes work and how they can be designed to ensure the return of their original values.

These projects are installed both at the Highvale and Battle River mining areas. Both are designed for five years of intensive study with the possibility for further monitoring beyond that period.

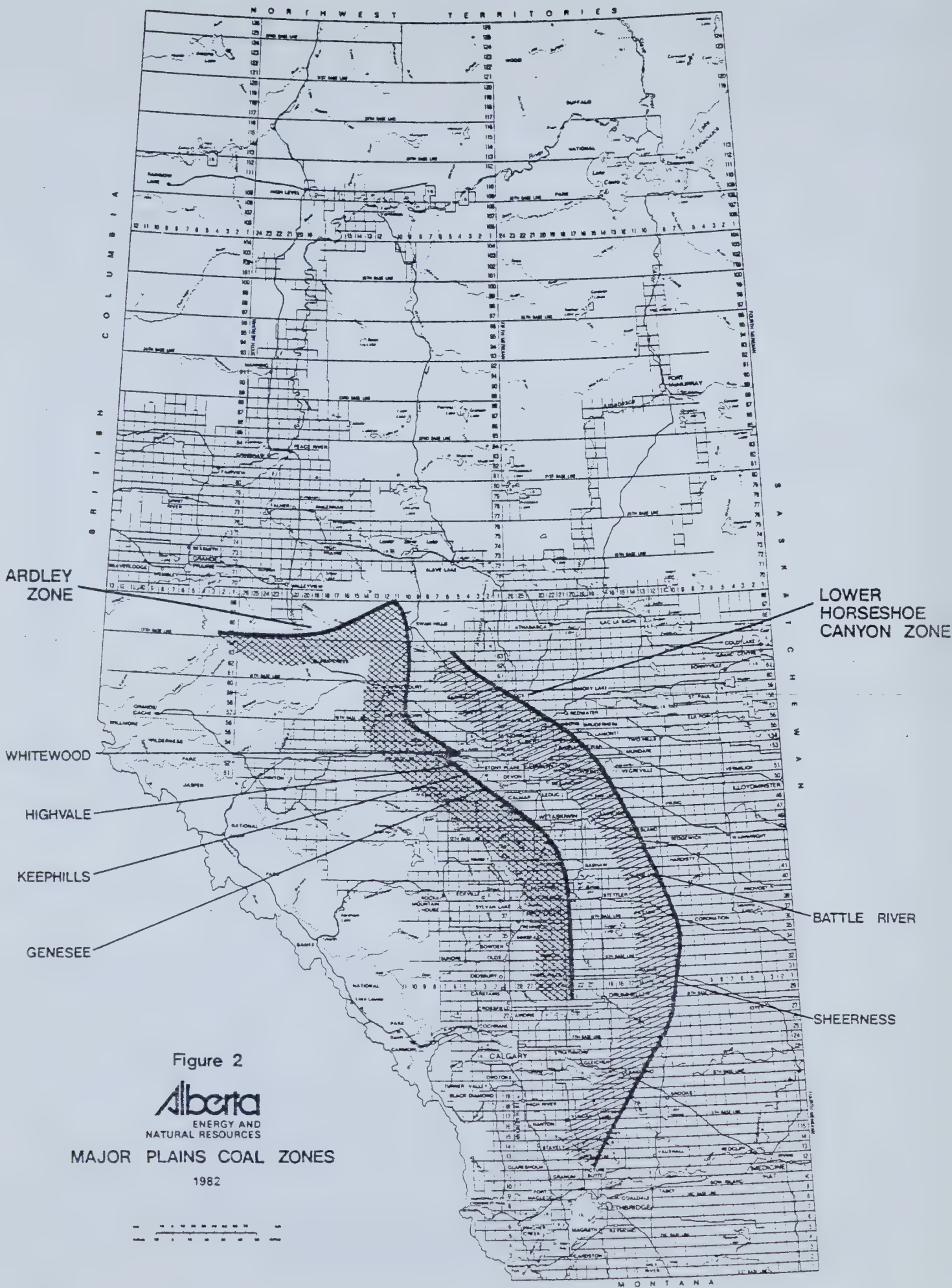


Figure 2

Alberta
ENERGY AND
NATURAL RESOURCES

MAJOR PLAINS COAL ZONES

1982

The program has been jointly designed and managed by Provincial Government and Coal Industry personnel.

Alberta Power Ltd., Luscar Ltd., Manalta Coal Ltd. and TransAlta Utilities Ltd. constructed the Test Plots at Battle River and Highvale. Research and maintenance activities for the Soil Reconstruction and Hydrology Programs are supported by the Heritage Savings Trust Fund.

1. Battle River Soil Reconstruction Project (82-5-LES)
L.A. Leskiw, Pedology Consultants Ltd.
2. Highvale Soil Reconstruction Project (82-13-SCH)
A.E.A. Schumacher, Montreal Engineering Co. Ltd.

Grain and forage yields are being evaluated on a series of soil reconstruction plots at the Battle River and Highvale Mining Areas. Treatments include: depth of subsoil (0 to 3m thicknesses) over sodic spoil, use of bottom ash as an impediment to upward salt migration, use of coal ash and gypsum as soil amendments and reconstruction of solonetzic topsoils using different horizons and mixtures. Lateral salt migration through reconstructed soils over spoil slopes is also being studied. The project began in 1979 at Battle River and construction was completed at Highvale in 1982.

Status: Cropping and Soil Sampling began at Battle River in 1981 and we now have two crop years of data. The first crop will be grown at Highvale in 1983. Each site will be studied intensively for at least five years.

3. Plains Hydrology and Reclamation Project (79-2-MOR)
S.R. Moran, Alberta Research Council

This study examines the impacts of surface mining on the regional groundwater, geology and soils. The main objectives include the identification of: 1) changes in groundwater quality and quantity after mining, 2) sources and release rates of groundwater contaminants (mainly salts), 3) changes in distribution of groundwater after mining (will the groundwater carry salts to the surface, will the watertable drop or will the watertable re-establish at premining levels) and 4) surface stability after mining (subsidence, piping).

Critical groundwater and geologic parameters will be identified which

may allow us to predict the "reclaimability" of a site prior to mining. This project began in 1979 and, like the Plains Soil Reconstruction Project it is duplicated at the Battle River and Highvale Mines.

Status: Battle River monitoring equipment is in place and the detailed soil survey has been completed. Two years of hydrologic data have been collected north of the Battle River, and one year on the south side.

Highvale - Installation and monitoring began in 1982. Each site will be intensively monitored for at least five years.

4. Physical and Chemical Changes in Stockpiled Topsoil (79-26-FUJ)
J. Fujikawa, Technical Development Branch, Alberta Environment

A topsoil stockpile near Bow City, Alberta, is being monitored along with undisturbed topsoil to determine whether adverse changes occur during storage. Ultimately this line of research will indicate how long topsoil can be stored before deterioration occurs.

Status: Ongoing

5. Contribution of Groundwater Organic Compounds to Salinization in Plains Surface Mining (79-22-HOD, 79-27-HOD)
G.W. Hodgson, University of Calgary

These projects examined the organic chemistry and microbiology of mine spoil salinization and were instituted to complement the inorganic chemistry approach taken in the Plains Hydrology Reclamation Project.

Status: Completed

Results: Final Reports 79-22-HOD, 79-27-HOD

B) PIPELINES

6. Evaluation of Pipeline Reclamation Practices on Agricultural Land (81-1-HAS)
W.J. Hastie, Hardy Associates (1978) Ltd.

This study addressed the effects of construction and reclamation of three pipeline sizes: 56", 36" and 10". A description of the major types of pipeline construction and reclamation techniques will be prepared and their difference relative to surface disturbance noted for various soil zones, types, and agricultural land uses.

Status: Completed 31 March 1982

Results: Final Report 81-1-HAS

C) FLY & BOTTOM ASH DISPOSAL

Four studies were conducted to characterize Alberta Coal Ashes and to assess their effects on soils and crops.

7. Chemical Characterization of Bottom Ash and Fly Ash from four Alberta Power Stations (78-2-MCC)
D. McCoy, Technical Development Branch, Alberta Environment
8. Plant Nutrient-Agronomic Potential of Coal Ash (78-20-MCC)
D. McCoy, Technical Development Branch, Alberta Environment
9. Radioactivity in Fly Ash (80-19-MCC)
D. McCoy, Technical Development Branch, Alberta Environment
10. Physical and Chemical Characterization of Fly Ash (78-5-P/R)
D. Pluth, J. Robertson, Soils Dept., University of Alberta

Ash samples were collected over a period of time and analysed to determine if fly and bottom ash chemistry varied among the various coal seams and power plants, and whether ash from a given source varies significantly through time. Various rates of fly ash and bottom ash were mixed with two soils and a sodic spoil to determine whether ash addition can enhance growth of barley and alfalfa. Levels of radioactivity in fly ash from several power plants in Alberta were surveyed. Fly Ash from five sources around Alberta were surveyed for physical and chemical properties. Plant toxicities were evaluated in greenhouse studies.

Status: Completed

Results: Published in Report #RRTAC 81-3

11. MOUNTAINS AND FOOTHILLS

Reclamation Objectives

- 1) Control of erosion on a wide variety of disturbances including coal mines, mineral exploration sites, coal ash pits and oil and gas well sites.
- 2) Return of forested lands to previous levels of productivity.
- 3) Return of wildlife range to previous levels of productivity.

The Problem

Reclamationists in the mountains and foothills face a wide variety of conditions. While some foothill sites are characterized by subdued terrain and moderate climate other sites, particularly in the mountains, present steep slopes, rocky spoil and a short growing season. On these problem sites summer droughts, chinook winds, erodible slopes and nutrient-poor soils are common.

On lower elevation foothill sites reclamation is expected to yield forests with commercial potential while on the higher elevation mountain sites erosion control, development of wildlife habitat and recreation potential are the reclamation objectives.

Reclaimed land in the mountains and foothills will not be as intensively managed as reclaimed agricultural lands would be. Also, topsoils and sub-soil layers tend to be thin and difficult to handle selectively. They nonetheless are a valuable source of plant nutrients. So while some mixing of horizons is inevitable how much is acceptable? How thick should the replaced soil layer be? Other sites simply have no salvageable topsoil and Reclamation must prepare the site so that a plant-soil system will develop which will perform its land use expectations without indefinite fertilization.

A) LANDSCAPE DESIGN

One of the most important aspects of Reclamation in the Mountains and Foothills is creation of stable reclaimable landscapes. This includes dump design (optimal slope angles and lengths, terracing) and pit backfilling. Another critical aspect of landscape design involves the creation of new watersheds. These must be designed to control water flows and siltation of surrounding waters.

1. Mountain and Foothill Dump Design (82-14-CH0)
R.G. Chopiuk, Coal Mining Research Center

Resloped overburden dumps in Alberta and British Columbia were surveyed to identify practical construction and resloping strategies.

Status: Ongoing

Results: Annual Report 82-14-CH0

B) SOIL RECONSTRUCTION

Soil Reconstruction in the Mountains and Foothills involves making the best use of limited soil materials. The objective is to improve the Root Zone over Rocky and Nutrient-Poor Spoils. At Grande Cache coal ash disposal sites must be revegetated with implications for building a soil on the ash surface.

Of particular interest is the reinstatement of commercial forest capability on mined land. Two test plots have been established in the Foothills by Luscar Ltd. and Union Oil of Canada Ltd. which compare various thicknesses and blends of soil materials for commercial tree growth. These projects were developed in consultation with RRTAC and are supported entirely by company funds.

2. Revegetation of Ash Disposal Sites, Grande Cache (79-1-MAC).
T.M. Macyk, Alberta Research Council

This project identified the thickness of capping material over coal ash required to support an erosion-controlling cover crop. This is a co-operative Project with McIntyre Mines Ltd.

Status: Completed

Results: Final Report 79-1-MAC

C) REVEGETATION

Reclamation programs may have several objectives in the Mountains and Foothills including development of forestry capability, wildlife habitat and watershed values. Our objective is to develop revegetation methods which will meet objectives without long-term maintenance. Within the revegetation problem area priorities have been identified for herbaceous cover (species selection, erosion control, fertilization, nutrients) and for shrub and tree cover (propagation, establishment).

SPECIES SELECTION

3. Selection of Native Grasses for Reclamation (79-7-WEI)

J. Weijer, University of Alberta/A. Naeth, Alberta Environmental Center

Many alpine and subalpine sites are difficult to reclaim simply because commercially available grasses and legumes either cannot survive or reproduce in the short growing season. This study is selecting lines of native grasses which are known to invade disturbances in the subalpine and alpine. Selections are made on the basis of commercial potential and fitness for reclamation.

Status: Ongoing, the Project has been transferred to the Alberta Environmental Center, Vegreville.

Results: Three lines of Agropyron species are presently undergoing testing for licencing application with the Canadian Department of Agriculture.

4. Native Grasses for Reclamation: Selected Line Adaptability Trials (79-23-WEI)

P. Ziemkiewicz, Alberta Energy and Natural Resources

By early 1979 the above study had produced nine selected lines of native grass species. To ensure that the selected lines had not lost their tolerance to high-elevation conditions in the process of development, a series of test plots was established: 1) to evaluate their fitness to subalpine and alpine conditions, 2) to compare their performance with selected agronomic grasses and 3) to evaluate their respective fertilizer requirements.

Status: Ongoing

Results: Report #RRTAC 80-1

5. Evaluation of Native-Agronomic Grass/Legume Mixes for Reclamation of Subalpine Disturbances (78-18-RUS)

H. Tomm, Alberta Forest Service

Certain agronomic grasses and legumes are known to quickly establish an erosion-controlling cover while native grasses generally grow more slowly. This experiment tests which of several native/agronomic seed mixes provides the best combination of erosion-control and long-term stability.

Status: Ongoing

6. Survey of Alberta Forest Service Native Grass Trials (82-12-TOM)

M. Mihajlovich

Between 1975 and 1977 a number of Test Plots were established in the Mountains and Foothills from Alpine to Boreal Forest conditions. Native Grass, Tree and Shrub container plantings were tested as well as various topsoiling

treatments. Other treatments included island transplants and various agronomic legumes. This study was undertaken in 1982 to: 1) Document the location of the Plots and 2) gather and synthesize all available information.

Status: Completed

Results: Final Report #82-12-TOM

EROSION CONTROL

7. Methods for Establishing Grass Cover on Unamended Coal Spoil
(80-11-TAK, 79-17-TAK)
S.K. Takyi, Alberta Forest Service

This study compares different seedling methods for native grass mixes (hydroseeding, broadcasting and raking, simulated drilling). Also various erosion-controlling mats, mulches and contouring treatments are evaluated.

Status: Ongoing

Results: ENR Report #152

8. Survey of Alberta Forest Service Reclamation Sites (78-1-LAR)
G. Laroi, University of Alberta, Forest Science Department

Reclamation roads and drilling sites were surveyed in 1978 to assess revegetation success 4 to 7 years after treatment. Permanent sampling plots were established which may be reassessed in the future to better understand plant succession on reclaimed sites.

Status: Completed

Results: Final Report 78-1-LAR

FERTILIZATION, NUTRIENTS

9. Factors which Accelerate Development of Stable Nutrient Cycles
(82-11-Z/T)
P. Ziemkiewicz, S.K. Takyi, Alberta Energy & Natural Resources

The effects of Topsoiling, Species Selection (Native vs Agronomic, Grass vs Legume) and Maintenance Fertilizer Regime are evaluated on a Subalpine Coal Mine with regard to plant development, distribution, uptake and cycling of nutrients.

Status: Ongoing

10. Survey to Determine the Occurrence of Microbial N-fixing Root Sheaths (79-8-L/R)
M.J. Rowell, Norwest Soils Ltd.

Preliminary work suggested that root sheaths may be a significant source of N-fixation for grasses growing in nutrient-poor soils. This survey was commissioned to look for root sheath occurrence on reclaimed and undisturbed areas. Correlations were made between plant vigor and root sheath occurrence. N-fixing rhizosheaths were found on grasses growing on disturbed sites more commonly than on undisturbed sites. Future work may involve isolation and identification of the N-fixing organisms. When available, the resulting inocula would be tested under field conditions to determine whether they have value as a reclamation treatment.

Status: Completed

Results: Final Report 78-8-L/R

11. Uptake of Nitrogen by Native Grasses (78-3-M/P)
D. Paton, University of Alberta

It is often assumed that native grasses require less nutrient than their agronomic counterparts. This study compared the nitrogen uptake rates of native and agronomic grasses to learn more about their nutrient requirements.

Status: Completed

Results: Final Report 78-3-M/P

TREE & SHRUB PROPAGATION

12. Native Shrub Seed Propagation Testing Project (80-16-KIN)
P. King, Alberta Forest Service

Methods for collecting, handling and treating seed of native shrub species with potential for reclamation will be evaluated to maximize propagation success.

Status: Ongoing

13. Factors Affecting Germination of Buffaloberry (82-1-K/H)
C. Keating, University of Alberta, Forestry Department

Buffaloberry (Shepherdia canadensis) is a valuable shrub for Reclamation, but it is difficult to propagate. This Study investigated methods for enhancing germination of Buffaloberry seed so that stock may be produced in large quantities for Mine Reclamation.

Status: Completed

Results: Final Report 81-1-K/H

TREE & SHRUB ESTABLISHMENT

14. Optimization of Erosion Control and Reforestation Potential
of Reclaimed Areas (79-16-MIH)
P. King, Alberta Forest Service

This study will identify the level of grass/legume cover which will prevent erosion yet permit tree seedling growth. This study will also identify methods for predicting the optimal levels of herbaceous cover.

Status: Ongoing

111. NORTHEAST ALBERTA

Reclamation Objectives

- 1) To develop techniques whereby a self-sustaining, erosion-free cover can be established on oil sand tailings pond dykes.
- 2) To return tailings sand storage and overburden dumps to productive forest.

The Problem

Northeast Alberta contains all of Canada's surface-mineable oil sands. Extraction of this valuable petroleum resource presents several problems for reclamation. By far the greatest problem lies with the tailings disposal systems currently employed.

At the end of its 25 year life a typical oil sand plant producing 19 900 cubic meters per day (125 000 barrels per day) of synthetic crude oil will require a 22 to 31 square kilometer (8.5 to 12 square miles) tailing pond. The liquid contents of the pond will consist primarily of 360 million cubic meters of sludge. The sludge will remain in a liquid state indefinitely and will be impounded behind dykes built of tailings sand. Dyke heights will reach from 55 to 100 meters above ground level. Erosion protection will be provided by a cover of grasses, legumes and shrubs. Because the tailings sand is devoid of nutrient and drains rapidly, amending materials (Muskeg, certain mineral overburdens) will be added to begin development of a soil.

Pits left after mining will be filled with tailings sand and overburden dumps will be constructed. These sites will also be reclaimed to a designated land use. Soil reconstruction and woody plant establishment in particular need further research.

Approach

As in the Mountains and Foothills, proper reclamation in Northeast Alberta will produce landform and plant community combinations which will fulfill their land use requirements without indefinite maintenance.

In order to pool resources and avoid duplication of effort, RRTAC and the industry's Oil Sands Environmental Study Group (OSESg) have initiated a joint Reclamation Research Program. Three priority areas have been identified:

- 1) Woody Plant Research
- 2) Soil Reconstruction
- 3) Equipment Development.

The Woody Plant Research Program is now underway and test plots for the Soil Reconstruction Research Program will be constructed in 1983.

) SOIL RECONSTRUCTION ON TAILINGS SAND

1. Soil Reconstruction Project: Phase I Literature Review (79-24-OSE)
R. Johnson, Montreal Engineering Co. Ltd.

This was a joint OSESG/RRAC project aimed at identifying available soil-building materials in the Oil Sands area and developing methods of combining these materials into productive soils. Phase I, which is a literature review and analysis of existing information was funded in 1979/80. This review identified treatments for the Test Plot Program which will constitute Phase II of the Soil Reconstruction Project.

Status: Completed

Results: Final Report 79-24-OSE

2. Reinstatement of Biological Activity in Reconstructed Soils (81-3-PAR, 78-4-PAR)
D. Parkinson, University of Calgary

The nature of micro organism establishment on reconstructed spoils was investigated in a series of field and laboratory studies. Emphasis centered on Fungal Decomposers and Micorrhizal Fungi and the influence of various amendments (peat, sewage sludge, inorganic fertilizers) on their populations.

Status: Completed

Results: Final Report 78-4-PAR, 81-3-PAR

3. Micorrhizal Potential in Reconstructed Soils (81-2-PAR)
D. Parkinson, University of Calgary

Micorrhizal Fungi nearly always enhance tree nutrition. This project will determine the survival and inoculum potential of Micorrhizal Fungi in undisturbed and stockpiled peat to be used in oil sand tailing reclamation. Also, Fungal species will be selected for use in Jack Pine inoculation programs and micorrhizal development will be monitored in field trials.

Status: Ongoing

) REVEGETATION

Revegetation in the Oil Sands will focus on establishing shrubs, commercial and non-commercial tree species and in some areas a grass-legume cover for erosion control. The latter is readily accomplished so the Revegetation Research Program concentrates on establishment of shrubs and trees.

4. Selection of Tree and Shrub Varieties for Oil Sand Reclamation
(79-13-DUN)
S.K. Takyi, P. King, Alberta Forest Service

In 1979 a test site in the oil sands area was planted with varieties of native and exotic tree and shrub species to help select those most suitable for oil sands reclamation.

Status: Ongoing

5. Survey Establishment and Maintenance Procedures (81-4-P/F)
R. Hermesh, Techman Engineering Ltd.
6. Review of Propagation Methods (81-5-WAT)
R. Hermesh, Techman Engineering Ltd.
7. Seed Collection for Shrub & Tree Trials (81-6-K/K)
D.J. Klym, Suncor Inc., P. King, Alberta Forest Service
8. Review of Sampling Methods (81-7-ROW)
M.J. Rowell, Norwest Soils Ltd.

These four Projects were preliminary to establishment of Field Trials in 1983. All were jointly supported by OSESG and RRTAC.

Status: Completed

Results: Final Reports: 81-4-P/F
81-5-WAT
81-6-K/K
81-7-ROW

IV. GENERAL

A number of projects will yield results applicable to reclamation problems throughout Alberta. These projects are listed below.

Projects

1. Reclamation Review (78-6-SIM)
H.P. Sims, Alberta Environment

This project will compile information from the international reclamation literature pertinent to Alberta. The Reclamation Review will not only serve as a handbook of reclamation techniques, it will also identify gaps in our reclamation knowledge and point the way for future research.

Status: Bibliography Completed

Results: Published Report #RRTAC 82-1

2. Reclamation Activities in Alberta (80-15-SIM)
H.P. Sims, Alberta Environment

Reclamation and reclamation research activity in Alberta were surveyed and presented in report form.

Status: Completed

Results: Published in Report #RRTAC 81-2

3. Cross Reference for Reclamation Review (80-13-WAL)
D.G. Walker, David Walker Assoc. Ltd.

This project will provide a cross reference of keywords, authors and subjects as part of the Reclamation Review.

Status: Completed

Results: Published in Report #RRTAC 82-1

4. Species Suitability Manual (79-5-W/P)
L.E. Watson, Techman Ltd.

This manual catalogued available information on the many species used

or useable in reclamation. This will help Reclamationists design seed mixes which are better adapted to their particular needs.

Status: Completed

Results: Published Report #RRTAC 80-5 Vol. I Grasses

Vol. II Forbs, Shrubs and Trees

"PROGRAM SUMMARY TO DATE"

PLAINS AGRICULTURAL LAND

OBJECTIVE: Restoration of Agricultural Capability

PROBLEM
AREA

RESEARCH
PRIORITIES

PROJECTS

DESCRIPTION

EXPENDITURES:
RRTAC
INDUSTRY
INVOLVEMENT

FROM
1 APRIL, 1978
TO 31 MARCH, 1983

Groundwater/ Geology	- Effects of Mining on groundwater supplies - Generation of Salts in Spoil - Transport of Salts near the Reclaimed Soil Surface - Subsidence after Reclamation - Effects of underground Ash disposal on groundwater - Overburden classification	79-2-MOR 79-22-HOD* 79-27-HOD* 80-14-MAR*	The Regions including and surrounding the Battle River and Highvale Mining areas are being intensively monitored to assess the effects of mining on the Soil, Water and ultimately, the Agricultural Resources. As significant concerns are identified remedial measures are also evaluated. Monitoring is in the third of five years at Battle River and in the first of five years at Highvale.	3,493,817	Joint Management and Project Review through Project Steering Committee, Site Access and Information sharing: Alberta Power Ltd. Manalita Coal, Luscar Ltd. and TransAlta Utilities
Soil Reconstruction	- Thickness of Subsoil required above Sodic Spoil - Effects of Slope on lateral salt transport - Reconstruction of Solonchetic Soils - Use of Bottom Ashes Soil Amendment - Effects of different Crops on thickness requirements - Changes in Topsoil during stockpiling	82-5-LES 82-13-SCH 79-6-SCH* 79-26-FUJ	Experimental Plots have been constructed on the Battle River and Highvale Mine areas and 1983 will be their second and first crop years respectively. The Plots will be intensively monitored annually for five crop years each.	332,167	Plot Construction; Joint Management and Project review through Project Steering Committee: Alberta Power Ltd., Luscar Ltd., Manalita Coal and TransAlta Utilities
Fly and Bottom Ash Disposal	- Chemical and Physical Properties of Alberta Fly & Bottom Ashes - Potential for use as Soil Amendment	78-2-MCC* 78-20-MCC* 78-5-P/R* 80-19-MCC*	Ashes from Five Alberta Sources were analyzed for both toxicity and Soil Amendment possibilities. This Program is completed and the results are published in Report #RRTAC 81-3.	12,176	Provision of Ash Samples: Alberta Power Ltd., TransAlta Utilities and Saskatchewan Power Ltd.
Pipelines	- Identify the best methods for handling Soil materials in pipeline construction in Agricultural land	81-1-IAS*	A Survey was made of Pipelines of various ages on all of our major Agricultural Soil types. Material handling methods were assessed and problem areas identified.	40,120	A member of the pipeline Industry sat on the Project Mgmt. Committee access to construction records, route locations and demonstrations.
				3,878,280	

MOUNTAIN AND FOOTHILLS COAL MINING

OBJECTIVE: Restoration of Forestry, Wildlife and Watershed Capabilities

FROM
1 APRIL, 1978
TO 31 MARCH, 1983
RRTAC
EXPENDITURE

PROBLEM AREA
RESEARCH PRIORITIES

INDUSTRY INVOLVEMENT

PROBLEM AREA	RESEARCH PRIORITIES	PROJECTS	DESCRIPTION	EXPENDITURE	INDUSTRY INVOLVEMENT
Landscape Design	Design & Construction of Stable Spoil Dumps	82-14-C110	Survey of Existing Reclaimed Dumps in Alberta and British Columbia to identify Practical Restoring Strategies	10,137	Information sharing on site demonstrations
	Water Management				
Soil Reconstruction	For Commercial Forestry Potential	Company Projects Coal Valley Luscar-Sterco Ltd. Obed-Marsh, Union Oil of Canada Ltd.	Forest Soil Reconstruction Plots, White Spruce and Lodgepole Pine planted on various reconstructed soil profiles.	0	100% Funding Luscar Ltd.
	For Erosion Control on Ash Dumps	79-1-MAC	Thickness of Soil required over Bottom/Fly Ash mix to support vegetation	50,371	100% Funding Union Oil Plot Construction and design McIntyre Mines
Revegetation	Species Selection	79-7-WE1 79-23-WE1 82-12-TOM 79-5-W/P 79-18-RUS	Development, assessment and Field Testing of Native Grasses for reclamation. Presentation of known information on Species for Reclamation	572,333	-
	Erosion Control	79-17-TAK 80-11-TAK 78-1-LAR* 82-9-LLO*	Mulches, Binders & Contouring Techniques for erosion control on coal spoil	17,475	-
Tree & Shrub Cover	Fertilization, Nutrients	82-11-Z/T 78-3-W/P 79-8-L/R	Identification of Treatments important to development of self-sustaining Plant Cover	32,453	-
	Propagation	80-16-KIN 82-1-K/H	Propagation of Shrubs of Reclamation	20,181	-
	Establishment	79-16-H111	Establishment of Tree Seedlings in Grass Cover	0	-
				702,950	

OIL SANDS

OBJECTIVE: Restoration of Forestry, Wildlife Capabilities and Erosion Control

FROM
1 APRIL, 1978
TO 31 MARCH, 1983
RRTAC
EXPENDITURESPROBLEM
AREARESEARCH
PRIORITIES

PROJECTS

DESCRIPTION

INDUSTRY
INVOLVEMENT

Identify Recipies for
Reconstructed soils
suitable for:
- Commercial Forest
- Non-Commercial Forest
- Erosion Control/
- Wildlife Habitat

78-4-PAR*
79-24-OSE*
81-2-PAR
81-3-PAR*

Identification of the chemical
and Microbiological properties
of peat, development of micorr-
hizal inoculants for Jack Pine
and other woody species, identif-
ication of amendment level require-
ments.
These studies are largely complete
and were fundamental in designing
the Oil Sand Soil Reconstruction
Plots which will begin construction
in 1983.

534,611

Joint Project Develop-
ment Management, review
and 80% Funding of
79-24-OSE Provision
of test site for
81-2-PAR

Soil
Reconstruction on
Tailings Sand

Shrub & Tree
- Selection
- Propagation
- Establishment
- Management

79-13-DUN
81-4-P/F*
81-5-WAT*
81-6-K/K*
81-7-ROW*

These projects consist of Tree and
Shrub selection, Seed collection,
development of Propagation Techniq-
ues, and Sampling Methods for use
on the Soil Reconstruction Plots to
be constructed in 1983.

14,499

Project development,
Joint/Management,
review and 50% Funding
of 81-4,5,6,
100% Funding of
81-7 ROW

Revegetation

549,110

For Incorporation of
Tailing Sand Amendments
(e.g. Peat, Clay)

(No Formal Projects or Contracts were commissioned under this priority. Rather
Government and Industry staff have jointly reviewed available equipment and have
arranged trials under operational conditions. The evaluation is continuing)

Equipment
Development

GENERAL **

Document the Findings Rec-
lamation Research activities
and assess implications for
Alberta operations

69,323

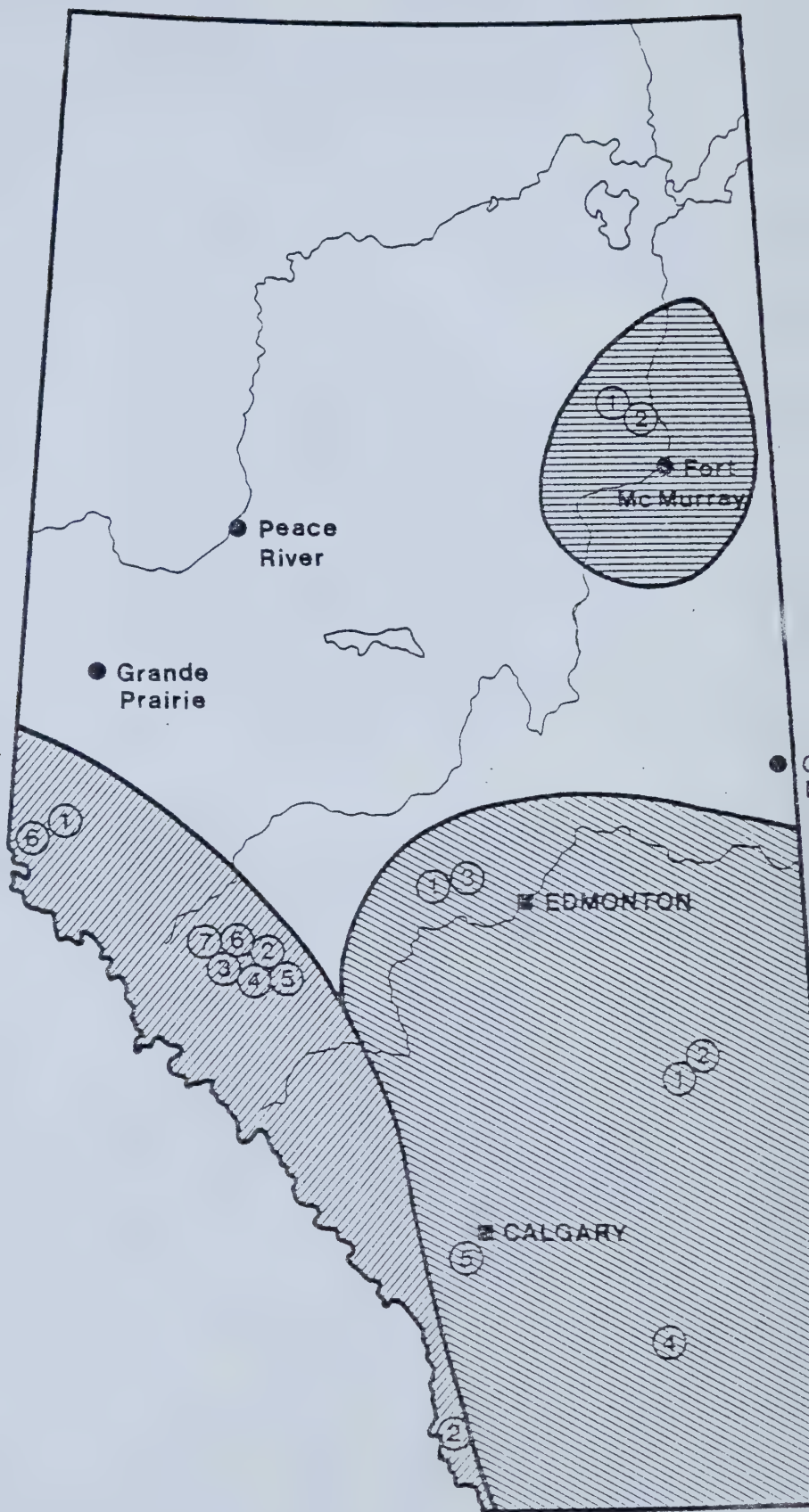
World wide Reclamation Literature
has been reviewed and condensed for
presentation in a Report which will
list and discuss existing inform-
ation as pertinent to Reclamation in
Alberta. The data base is accessible
through The University of Alberta
computing system. See Reports #RRTAC
82-1- and 81-2.

69,323

Total for all RRTAC Programs as of 31 March, 1983

5,199,663

** Projects with Province wide application



LOCATION OF FIELD PLOTS

PLAINS

- 1) 79-2-MOR FORESTBURG, HIGHVALE.
- 2) 82-5-LES FORESTBURG.
- 3) 82-13-SCH HIGHVALE.
- 4) 79-26-FUJ BOW CITY.
- 5) 78-4-PAR CALGARY.

MOUNTAINS & FOOTHILLS

- 1) 79-1-MAC GRANDE CACHE.
- 2) 79-16-MIH COALVALLEY, CROWSNEST.
- 3) 79-17-TAK CADOMIN.
- 4) 79-18-RUS CADOMIN.
- 5) 80-11-TAK CADOMIN.
- 6) 79-23-WEI CADOMIN, GRANDE CACHE.
- 7) 82-11-Z/T CADOMIN.

NORTHEAST OIL SANDS

- 1) 81-2-PAR MILDRED LAKE.
- 2) 79-13-DUN MILDRED LAKE.

RESEARCH PROJECTS 1982-83

Managing Agency (Research Organization Principal Investigator)	Project #	Research Subject	RRTAC Budget # (1982-83)
Alberta Energy & Natural Resources Alberta Forest Service			
(Alberta Research Council T.M. Macyk)	79-1-MAC	Revegetation of Ash Disposal Pits, McIntyre Mines, Grande Cache	19,260 <u>1</u>
(Alberta Forest Service S.K. Takyi, P. King)	79-13-DUN	Selection of Woody Plants for Oil Sand Reclamation	0 <u>2</u>
(Alberta Forest Service P. King)	79-16-MIH	Establishment of Tree and Shrub Seedlings in Erosion Controlling Cover, Coal Valley, Crowsnest	0
(Alberta Forest Service S.K. Takyi)	79-17-TAK	Use of Mat Mulches on Difficult Slopes, Cadomin	0
(Alberta Forest Service H. Tomm)	79-18-RUS	Evaluation of Native-Agronomic Grass and Legume Mixes, Cadomin	0
(Alberta Forest Service S.K. Takyi)	80-11-TAK	Methods of Establishing Native Grass on Un- amended Coal Spoil, Cadomin	0
(Alberta Forest Service P. King)	80-16-KIN	Native Shrub Seed Propagation Testing Project	3,000
(Techman Ltd. R. Hermesh)	81-5-WAT	Shrub Propagation Literature Review	7,475
(University of Alberta Forestry Department C. Keating)	82-1-K/H	Factors Affecting Germination of Buffaloberry	15,181
(Mihajlovich Environmental Services Ltd. M. Mihajlovich)	82-12-TOM	Survey of Native Grass Plantings	7,500

Managing Agency (Research Organization Principal Investigator)	Project #	Research Subject	RRTAC Budget # (1982-83)	
Alberta Energy & Natural Resources				
(Scientific & Engineering Services P.F. Ziemkiewicz/S.K. Takyi)	82-11-Z/T	Development of Stable Nutrient Cycles on Subalpine Coal Spoil	6,755	
(Scientific & Engineering Services P.F. Ziemkiewicz)	79-23-WEI	Selected Lines of Native Grasses Alpine and Subalpine Test Plots	0	
(Public Lands Division D. Lloyd)	82-9-LL0	Erosion Control for Sandy Sites	11,330	
(Coal Mining Research Center R. Chopiuk)	82-14-CH0	Survey of Mountain Waste Dumps and Resloping Operations	10,137	
Alberta Environment <u>Research Management Division</u>				
(Research Management Division H.P. Sims)	78-6-SIM	Review and Presentation of Reclamation Information Pertinent to Alberta	0	
(Alberta Research Council S.R. Moran)	79-2-MOR	Hydrologic Impacts of Plans Surface Coal Mining, Forestburg, Highvale	1,099,963	
(Alberta Environmental Technical Development Branch C. Palmer)	79-6-SCH	Techniques for Restoring Crop Production after Surface Mining, Forestburg - Remain- ing Soil Analyses from 1981-82	4,132	3
(Genetics Dept., University of Calgary/Alberta Environmental Center J. Weijer/A. Naeth)	79-7-WEI	Development of Native Grasses for Reclamation	79,540	4
(Biology Dept., University of Calgary D. Parkinson)	81-2-PAR	Micorrhizal Development in Reconstructed Soils	116,700	

<u>Managing Agency (Research Organization Principal Investigator)</u>	<u>Project #</u>	<u>Research Subject</u>	<u>RRTAC Budget # (1982-83)</u>
(Pedology Consultants Ltd. L. Leskiw)	82-5-LES	Battle River Soil Reconstruction Project	130,000
(Montreal Engineering Co. Ltd. A. Schumacher)	82-13-SCH	Highvale Soil Reconstruction Project	25,169
Alberta Environment <u>Technical Development Branch</u>			
(Technical Development Branch J. Fujikawa)	79-26-FUJ	Physical and Chemical Changes in Stockpiled Topsoil	0
		TOTAL	1,536,142

- 1/ Cooperatively funded with McIntyre Mines Ltd.
- 2/ Projects requiring no RRTAC Budget are fully funded by the Managing Agency
- 3/ Cooperatively funded with Alberta Power Ltd., Luscar Ltd. and Manalta Coal
- 4/ Cooperatively funded with Parks Canada

LAND CONSERVATION
AND
RECLAMATION COUNCIL

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ALBERTA RECLAMATION CONFERENCE
Alberta Chapter, Canadian Land Reclamation Association
Edmonton, Alberta
February 23 to 24, 1983

THE DEVELOPMENT AND RECLAMATION REVIEW PROCESS:
CHANGES AND NEW DIRECTIONS

Larry K. Brocke, M.Sc. P.Ag.
Chairman, Development and Reclamation
Review Committee

ABSTRACT

A discussion of the Development and Reclamation Review Process is presented in the context of changes suggested in last years presentation to this conference. The concept of land capability is introduced as a new direction in land reclamation that will require a continued open line of communication between government and industry.

In my presentation to this conference last year I related to you the stage in the overall approval procedure where the Development and Reclamation Review and Approval process occurs, detailed the review and approval process, and identified the committee. Throughout that presentation I made several suggestions that I believed would help to facilitate the review and approval process.

This morning I would like to go back to last years presentation for a few minutes to give you an update on the committee representation and discuss some of the changes that have occurred. Then I would like to present some new directions that are evolving.

The changes to the committee membership that have occurred over the past year include the withdrawal of the Alberta Research Council and replacement by Alberta Environment, Earth Sciences Division; the addition of Alberta Economic Development; and two personnel changes within existing department representation.

The committee, as it stands today, has the following representation:

Alberta Agriculture - Soils Division	- John Hermans
Alberta Culture - Archaeological Survey	- Paul Donahue
Alberta Energy and Natural Resources	
- Forest Service	- Jeff Bondy
Alberta Energy and Natural Resources	
- Fish and Wildlife	- Ron Millson
Alberta Energy and Natural Resources - Lands	- Loren Winnick
Alberta Energy and Natural Resources	
- Energy Sector	- Paul Ziemkiewicz

ERCB - Coal Department	- Khalid Jamil
ERCB - Oil Sands Department	- Brahm Prasad
Alberta Environment - Land Reclamation	- Dennis Bratton
Alberta Environment - Standards and Approvals	- Wally Nahulak
Alberta Environment - Earth Sciences	- Roger Hardick
Alberta Municipal Affairs - Regional Planning	- Gord Hannon
Alberta Recreation and Parks - Parks	- Stewart Loomis
Alberta Transportation - Planning and Research	- Don Szarko
Alberta Economic Development - Energy Sector	- Chrys Dmytruk

I should note that although the Research Council has withdrawn its representation from the committee we are still able to call on their technical expertise as required.

Another change that was instituted, with the consensus of the committee, was the appointment of Paul Ziemkiewicz as Vice-Chairman. The rationale was two-fold: firstly, and most obvious, I believed a Vice-Chairman was necessary to chair meetings in my absence; and secondly, as chairman of the Reclamation Research Technical Advisory Committee, Paul is able to provide a liaison between the research and regulatory bodies. This liaison provides the committee with the technical expertise to assist in application of the results of research to the Development and Reclamation approval.

With regard to the stage in the overall approval procedure I indicated that the Development and Reclamation review and approval process officially begins subsequent to the mine permit application and concurrent with the mine license application. This sequencing was

apparently contradictory to what some other agencies believed and, to say the least, created a good deal of confusion in industry. In an attempt to resolve this issue a number of meetings were held between Alberta Environment and the ERCB. The result of these meetings was the preparation and issuance of joint informational letter IL82-18 in July, 1982. This informational letter detailed the procedure for processing coal mine permit applications and clarified where the Development and Reclamation application would be appropriately submitted and I quote:

"Following the hearing, the applicant may apply through the Coal Department for a Development and Reclamation Approval, as prescribed in the Regulated Coal Surface Operations Regulations, for part or all of the project, depending upon the level of available information contained in the EIA, matters raised at the hearing, and the Board's decision report."

With regard to some of the suggestions I made last year to facilitate the review and approval process the following changes have occurred. First, I indicated that the Environmental Assessment Division was going to implement a transfer of information system to inform the Development and Reclamation Review Committee of any upcoming major projects. This system has been implemented and is serving the committee. For example, there were two permit applications to the ERCB for major projects last year. Through this system the committee became aware of the project, had an opportunity to identify some concerns early, and participated in the preparation for the ERCB public hearings. After the hearings a summary of the hearing proceedings, identifying major issues, was provided to the committee. In this way the committee has been kept informed of the status of these projects which will certainly facilitate the Development and Reclamation review and approval process when the application is received.

Secondly, I suggested the importance to industry to establishing early contact with the committee and encouraged an open line of communication between industry and the committee throughout the life of the project. I believed this would achieve several goals, not the least of which was to ensure the submission of complete applications. It also served to put faces with names, on both the industry and committee sides which has certainly reduced the confrontation atmosphere. Over the past year the committee, in whole, or in part has met with most of the coal and oil sands operators on more than one occasion and resolved many approval issues.

One of the major issues that was resolved was the "three metre dilemma" with regard to soil replacement. Through communication and around the table discussion a suitable compromise was reached which will be in effect until such time as research proves different.

The committee also visited many of the mine sites during the year to get a better feel for ground conditions. I must express my appreciation, on behalf of the committee, to industry for the welcome we received, without exception. It is my intention that this open line of communication that has evolved will remain and improve.

Two other events occurred during the past year which have resulted in changes and ultimately new directions. Both of these events involved interaction between industry and government although not the Development and Reclamation committee directly. The first event, which I have referred to previously, involved industry's reaction to the Proposed Soil Quality Criteria document and the ultimate resolution of the "three metre dilemma", and acceptance of the inventory methodology outlined. Further to the three metre issue industry's review of the document has resulted in a recommendation to the Alberta Soils Advisory Committee requesting that the Soil Quality

Criteria subcommittee review and revise the document to reflect industry's concerns. This process is presently under way and a revised edition will be printed and released in due course.

The second event involved industry's review of the Development and Reclamation application guidelines. These guidelines were reviewed by the Coal Association's Environment and Reclamation Committee. The result of this review was a request by the Chairman of the Council to the Development and Reclamation committee to re-write the Development and Reclamation application guidelines. The intent of the re-write was to consider industry's concerns and to revise the 1977 Guidelines for the Reclamation of Land in Alberta. This process has been under way for some time now and the committee is ready to submit it's revised version of the guidelines to the Chairman of the Council.

A clarification and refinement that is evolving out of this process is the apparent need to adopt the concept of land capability as a method of measuring reclamation rather than productivity and land use. The goal of reclamation is thus to minimize the effect of the surface disturbance and to assure the re-establishment of equivalent or better land capabilities upon the conclusion of reclamation. For these purposes land capability can be defined as the intrinsic ability (ie. ability unaltered by any level of future management inputs activities or alterations) of land resources to support a given use type, intensity and quality on a sustained basis. This term refers to an evaluation or rating of inherent or natural abilities of land resources to provide for use. It includes any existing abilities and conditions which are the result of alterations or management practices prior to the development. As ordinarily used, land capability is an expression of the effect of physical land conditions, including climate, on the ability of the land to support various uses such as agriculture, forestry, wildlife, and recreation. Continued dialogue with industry regarding this concept will be welcomed.

ALBERTA RECLAMATION CONFERENCE
CANADIAN LAND RECLAMATION ASSOCIATION
EDMONTON, ALBERTA
FEBRUARY 23 TO 24, 1983

THE FUNCTION AND RESPONSIBILITY
OF THE REGULATED OPERATIONS BRANCH
OF ALBERTA ENVIRONMENT

DENNIS L. BRATTON, P. ENG.
HEAD, REGULATED OPERATIONS BRANCH

ABSTRACT

HOW THE REGULATED OPERATIONS BRANCH FITS IN WITH THE LAND RECLAMATION DIVISION AND THE LAND CONSERVATION AND RECLAMATION COUNCIL IS DISCUSSED. THE TYPES OF DEVELOPMENTS INVOLVED WITH, AND THE APPROVAL FUNCTION OF THE BRANCH IS DESCRIBED AS IS THE BRANCH'S INPUT INTO LARGER PROJECTS REVIEWED BY THE DEVELOPMENT AND RECLAMATION REVIEW COMMITTEE.

THE PROGRESS MADE, THE PROBLEMS ENCOUNTERED AS WELL AS OUR FUTURE DIRECTION ON PIPELINE, TRANSMISSION LINE AND GRAVEL DEVELOPMENTS ARE DISCUSSED.

THE FUNCTION AND RESPONSIBILITY OF
THE REGULATED OPERATIONS BRANCH

BY

DENNIS L. BRATTON, P. ENG.

A MAJOR FUNCTION OF THE REGULATED OPERATIONS BRANCH IS REVIEWING AND COORDINATING AN INTERDEPARTMENTAL REVIEW OF, DEVELOPMENT AND RECLAMATION APPLICATIONS MADE FOR DEVELOPMENT AND RECLAMATION APPROVALS TO THE LAND CONSERVATION AND RECLAMATION COUNCIL.

FIGURE 1 IS A FUNCTIONAL ORGANIZATION CHART SHOWING THE RELATIONSHIP OF THE LAND RECLAMATION DIVISION AND THE LAND CONSERVATION AND RECLAMATION COUNCIL.

THE FOLLOWING ARE TYPES OF APPLICATIONS THAT ARE REVIEWED BY THE BRANCH FOR DEVELOPMENT AND RECLAMATION APPROVAL:

- A) SMALL COAL MINES (THAT PRODUCE LESS THAN 50,000 TONS/YEAR)
- B) OIL SANDS TEST FACILITIES OR INSITU DEVELOPMENTS
- C) PIPELINES GREATER THAN 150 MM IN DIAMETER AND 16 KM IN LENGTH
- D) GRAVEL PITS THAT WILL DISTURB MORE THAN 5 ACRES OF PRIVATE LAND
- E) ELECTRIC TRANSMISSION LINES OF 69 KV OR MORE (NO D & R REQUIRED, BRANCH RECOMMENDS MINISTERIAL APPROVAL BY THE MINISTER OF ENVIRONMENT FOR THE PERMIT TO CONSTRUCT)

OTHER SIGNIFICANT FUNCTIONS OF THE BRANCH ARE:

- I) CHAIRS THE CROWN MINERAL DISPOSITION REVIEW COMMITTEE WHICH REVIEWS MINERAL LEASES PRIOR TO THEIR SALE TO SEE IF THERE ARE ENVIRONMENTAL REASONS WHY CONDITIONS SHOULD BE PLACED ON THE LEASE OR IF THE LEASE, SHOULD IN FACT, BE OFFERED FOR SALE.
- II) CHAIRS THE EXPLORATION REVIEW COMMITTEE WHICH REVIEWS APPLICATIONS FOR COAL EXPLORATIONS AND MAKES RECOMMENDATIONS FOR APPROVAL TO THE CHAIRMAN OF THE COUNCIL.

FUNCTIONAL ORGANIZATION

ALBERTA ENVIRONMENTS LAND RECLAMATION DIVISION AND

LAND CONSERVATION AND RECLAMATION COUNCIL

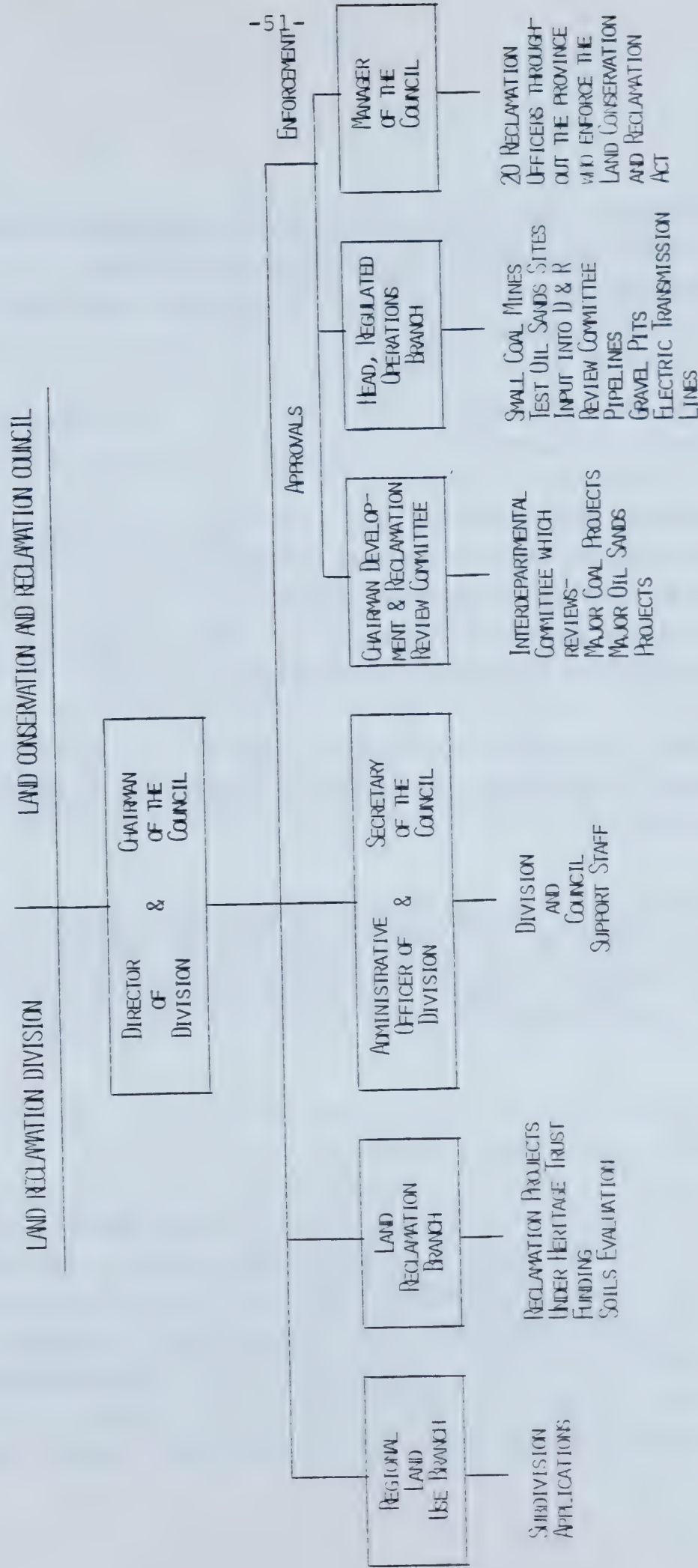


FIGURE 1

- III) PROVIDES PROFESSIONAL ADVISE TO THE RECLAMATION OFFICERS WHO ENFORCE THE DEVELOPMENT AND RECLAMATION APPROVAL.
- IV) PROVIDES INPUT INTO THE D & R REVIEW COMMITTEE ON MAJOR COAL AND OIL SANDS APPLICATIONS.

THE BRANCH'S PRESENT STAFF CONSIST OF TWO AGROLOGISTS, FOUR GEOGRAPHERS, A FORRESTER AND AN ENGINEER, PLUS CLERICAL STAFF.

NOW WHEN I WAS FIRST ASKED TO SPEAK TODAY BY MALCOLM ROSS, IT WAS TO TALK ON WHAT IS NEW IN THE WORLD OF GOVERNMENT AND WHAT OUR PRESENT DIRECTIONS ARE WITH RESPECT TO RECLAMATION. SO NOW THAT YOU HAVE A LITTLE BACKGROUND I WILL GO THROUGH THE TYPES OF DEVELOPMENTS WE DEAL WITH AND WHAT OUR PRESENT THINKING AND INTENTIONS ARE.

FIRST, ON SMALL COAL MINES THERE IS NOTHING NEW IN THIS DEPARTMENT, SOME RECLAMATION IS GETTING DONE AT THE 8 SMALL MINES IN THE PROVINCES.

SECOND, OIL SAND TEST SITES - THE REQUIREMENT FOR D & R APPROVAL FOR THESE PROJECTS ARE FAIRLY RECENT BUT THE APPROVALS ARE QUITE STRAIGHT FORWARD. THE ONLY INFORMATION REQUIRED IS A SOIL SALVAGE PLAN, A WATER MANAGEMENT PLAN AND A FINAL RECLAMATION PLAN.

PIPELINES

FIRST, I WOULD LIKE TO GIVE YOU A LITTLE HISTORY ON THE REGULATED OIL AND GAS PIPELINE SURFACE OPERATION REGULATIONS. THE REGULATION WAS PASSED IN 1976 AND REQUIRED APPROVAL OF ALL PIPELINE APPLICATIONS MADE TO THE ERCB EXCEPT FOR FLOW LINES, SECONDARY LINES AND SOME OF THE MINOR TYPES OF LINES. SINCE THE ERCB GETS 3,000 TO 4,000 PIPELINE APPLICATIONS A YEAR, WE WERE RECEIVING MANY HUNDREDS OF PIPELINE APPLICATIONS, MANY VERY SHORT AND ENVIRONMENTALLY INSIGNIFICANT. IT

WAS 1978 BEFORE WE GOT A FULL TIME PIPELINE COORDINATOR. IN 1979 THE "REGULATED OIL AND GAS PIPELINE SURFACE OPERATION REGULATIONS" WAS CHANGED SO THAT ONLY PIPELINES OVER 6 INCHES IN DIAMETER AND 10 MILES (150 MM AND 16 KM) IN LENGTH REQUIRED D & R APPROVALS. THE NUMBER OF APPROVALS REQUIRED DROPPED FROM MANY HUNDREDS TO 30 TO 50 MAJOR PROJECTS PER YEAR.

WE THEN DEVELOPED STANDARDIZED INFORMATION REQUIREMENTS FOR APPLICATIONS WHICH WERE FINALIZED IN 1980. OUR NEXT OBJECTIVE WAS TO GET AN ENVIRONMENTAL PROTECTION PLAN FOR EACH PIPELINE AND TO GET THIS PLAN INCLUDED IN THE CONSTRUCTION SPECIFICATION AS PART OF THE CONTRACT. THIS WAY THE OWNER HAS PAID THE CONTRACTOR FOR DOING THE WORK INVOLVED IN PUTTING THE ENVIRONMENTAL PROTECTION PLAN IN PLACE. CONSEQUENTLY, THE OWNER IS INTERESTED IN SEEING THAT WORK THAT HE HAS PAID FOR GETS DONE. THE FIRST TIME WE WERE SUCCESSFULL IN THIS, THE CONTRACTOR CAME TO THE OWNER WITH AN EXTRA BILL FOR ENVIRONMENTAL WORK THAT HE DIDN'T THINK HE WOULD HAVE TO DO ALTHOUGH IT WAS IN THE CONTRACT.

WE HOPE THAT THE INCLUSION OF THE ENVIRONMENTAL PROTECTION PLAN IN THE GENERAL CONSTRUCTION CONTRACT WILL BECOME A STANDARD PRACTICE SO THAT THE CONTRACTORS ARE AWARE OF WHAT IS REQUIRED PRIOR TO THEIR CONTRACT BIDDING.

ANOTHER AREA WHERE WE HAVE TAKEN A STAND IS ON THE SALVAGE OF TOPSOIL, IN PARTICULAR, ON CULTIVATED LANDS DURING WINTER CONSTRUCTION. WE RECEIVED LOTS OF ARGUMENTS WHY IT CAN'T BE DONE, WHY IT SHOULDN'T BE DONE, AND WHY ITS UNREASONABLE. BUT BASICALLY, ALL REGULATED PIPELINES WHICH HAVE BEEN BUILT ACROSS CULTIVATED LAND DURING THE PAST TWO WINTERS HAVE HAD TOPSOIL SALVAGED. AT LEAST THE EFFORT HAS BEEN MADE, SOME PROCEDURES WORK BETTER THAN OTHERS, AND WE ARE PRESENTLY EVALUATING THESE PROCEDURES.

ANOTHER POSITION WE HAVE TAKEN, WITH SOME SUCCESS, IS THAT THE OWNER SHOULD HAVE TRAINED ENVIRONMENTAL INSPECTORS ON THE CONSTRUCTION SITE AT ALL TIMES. ALL PIPELINE COMPANIES HAVE ENGINEERING INSPECTORS TO LOOK AFTER THE PIPE CONSTRUCTION, TO MAKE SURE ITS PROPERLY WELDED, WRAPPED AND COVERED ACCORDING TO THE CONTRACT. NORMALLY, THE SAME INSPECTOR IS ALSO RESPONSIBLE FOR THE ENVIRONMENTAL WORK. THIS ARRANGEMENT DOESN'T WORK AS THIS ENGINEERING INSPECTOR'S CONCERN IS WITH THE PIPELINE NOT WITH THE ENVIRONMENT. WE PROBABLY HAVE ABOUT A 30% SUCCESS RATE OF HAVING ENVIRONMENTAL INSPECTORS ON PROJECTS. THERE ARE FEWER FOUL UPS WITH THESE PEOPLE ON THE JOB AND IT IS MY OPINION THAT THEY ARE COST EFFECTIVE FROM THE OWNERS POINT OF VIEW.

CURRENTLY, WE ARE CONTINUING OUR EFFORTS TO GET SOILS INFORMATION ON THE PIPELINE ALIGNMENT AND THEN TO HAVE THE SOIL SALVAGE AND REPLACEMENT PLAN REFLECT THE SOILS INFORMATION PROVIDED. WE ARE HAVING SOME SUCCESS IN GETTING THE SOILS INFORMATION AND WE ARE WORKING ON GETTING THE OPERATORS TO USE THAT INFORMATION IN PLANNING THEIR RECLAMATION. MY OWN OPINION IS THAT THE PROFESSIONAL SOILS PEOPLE WHO DO THE SOILS INVENTORY SHOULD ALSO BE RESPONSIBLE FOR MAKING RECOMMENDATIONS TO THE PIPELINE COMPANY ON SOILS HANDLING AND REPLACEMENT PROCEDURES. THE SOIL SCIENTIST SEEMS TO BE THE ONLY ONE WITH THE KNOWLEDGE, AND MORE IMPORTANT, THE SIGNIFICANCE OF THIS KNOWLEDGE TO THE RECLAMATION PLAN.

GRAVEL OPERATIONS AND DEVELOPMENT AND RECLAMATION APPROVAL

THE PRESENT SAND, GRAVEL, CLAY AND MARL SURFACE OPERATIONS REGULATION WAS PASSED IN MAY OF 1982. THIS REGULATION APPLIES TO GRAVEL PITS THAT ARE ON PRIVATE LAND AND THAT HAVE DISTURBED, OR WILL DISTURB MORE THAN FIVE ACRES OF LAND. IT IS ESTIMATED THAT THERE ARE IN FACT ON PUBLIC LANDS, OVER 1,000 SUCH PITS IN THE PROVINCE AND DURING ANYONE YEAR ABOUT 1/2 OF THEM WOULD BE OPERATING. THE AVERAGE

SIZE OF THESE PITS IS 25 ACRES AND SO THE EXTENT OF THE SURFACE DISTURBANCE IS ABOUT 40 SQUARE MILES. MUCH OF THIS LAND WAS PRODUCTIVE FARM LAND AND MOST OF IT HAS LOST SOME, OR ALL, OF ITS AGRICULTURAL CAPABILITY. THIS IS MORE THAN THREE TIMES THE AREA DISTURBED BY COAL MINING ON AGRICULTURAL LANDS.

ANOTHER PROBLEM IS THAT, WHEREAS IN COAL YOU MIGHT HAVE TEN OPERATORS ALL WITH CONSIDERABLE FINANCIAL AND HUMAN RESOURCES, IN THE GRAVEL INDUSTRY YOU MIGHT HAVE 200 OPERATORS WITH VARIOUS RESOURCES.

YET ANOTHER ASPECT IS OUR SOCIETY'S CONCEPT OF OWNERSHIP. A LITTLE HISTORY IS IN ORDER HERE. IN THE 1950'S THE PROVINCE PASSED THE SAND, GRAVEL, CLAY AND MARL ACT WHEREIN THESE RESOURCES WERE BY LAW DECLARED INTO NON MINERALS AND THEY WERE DEEMED TO BE PART OF THE LAND. THIS GAVE OWNERSHIP OF THE GRAVELS TO THE LAND OWNER. FOR A LAND OWNER IT IS VERY DIFFICULT TO TURN DOWN MORE MONEY FOR GRAVEL THAN THE LAND IS WORTH AS FARM LAND. LIKEWISE, THE GRAVEL COMPANY MAY BE CONCERNED WHEN THEY HAVE TO SPEND TWICE OR THREE TIMES THE RESALE VALUE OF THE LAND ON RECLAIMING IT TO AN AGRICULTURAL STANDARD.

THESE ARE GENERAL PROBLEMS BUT WE HAVE MANY SPECIFIC PROBLEMS LIKE:

- A) WHERE ARE ALL THE PITS
- B) WHO IS THE OPERATOR
- C) WHO IS THE LAND OWNER
- D) HOW DO YOU EXPLAIN TO AN OPERATOR, THAT YOU WANT TO SEE A LIFE OF MINE PLAN WITH THE SEQUENCE OF MINING OPERATIONS AND A FINAL RECLAMATION PLAN WHEN THE OPERATOR MAY NOT BE EXPERIENCED IN THESE MATTERS.

WE ARE ALSO WORKING WITH ALBERTA TRANSPORTATION WHICH USES ABOUT HALF OF THE GRAVEL IN THE PROVINCE AND THE COUNTIES WHO ALSO USE A LOT.

FROM MY POINT OF VIEW IT IS ESSENTIAL TO BE ABLE TO SHOW INDUSTRY THAT THE PROVINCIAL AND LOCAL GOVERNMENTS ARE GOING TO RECLAIM THEIR PITS. WE ARE MAKING PROGRESS ON THIS FRONT.

ALL GRAVEL OPERATIONS WERE SUPPOSED TO HAVE DEVELOPMENT AND RECLAMATION APPROVAL BY JULY 1, 1982. TO DATE, ABOUT 100 APPROVALS HAVE BEEN GRANTED, BUT THERE ARE MANY TIMES THAT NUMBER OF PITS OUT THERE WITH NO APPROVALS. OUR PLAN TO GET THE JOB DONE WITH THE LIMITED RESOURCES AVAILABLE INVOLVES FIRST, AN INVENTORY OF MOST OF THE PITS IN THE PROVINCE - THIS IS ALMOST COMPLETE; SECOND AN ADVERTISING PACKAGE TO EACH OPERATOR - THESE WILL BE SENT OUT ON A COUNTY BY COUNTY BASIS.

WE PLAN TO FOLLOW UP WITH EACH OPERATOR UNTIL WE GET ADEQUATE INFORMATION TO RECOMMEND GRANTING A D & R APPROVAL. AT PRESENT WE HAVE ADVERTIZED IN FOUR COUNTIES AND HAVE ABOUT HALF OF THE PITS IN THESE FOUR COUNTIES APPROVED.

I WOULD NOT LIKE TO LEAVE YOU WITH THE IDEA THAT NO RECLAMATION IS BEING DONE ON GRAVEL PITS. SOME COMPANIES WERE RECLAIMING THEIR PITS LONG BEFORE THE REGULATIONS WERE DECLARED. OTHER COMPANIES STARTED AS SOON AS REQUESTED. HOWEVER IT WILL TAKE A LOT OF COMMUNICATING BEFORE THE MAJORITY OF THE OPERATORS UNDERSTAND THE REQUIREMENTS AND OPERATE BY THEM.

DEVELOPING RESPONSIBLE AND PRACTICAL
RECLAMATION LEGISLATION IN ALBERTA -
IS THE CO-OPERATIVE SPIRIT ALIVE?

ALBERTA RECLAMATION CONFERENCE
ALBERTA CHAPTER
CANADIAN LAND RECLAMATION ASSOCIATION
FEBRUARY 23, 1983, EDMONTON, ALBERTA

P.D. Lulman, Canadian Land Reclamation Association

Abstract:

A brief description is made of reclamation legislation in Alberta. The importance of guidelines to setting acceptable approvals is emphasized. The technical aspects of guidelines and approvals are proposed as the areas most in need of revision. Objective guidelines mutually acceptable to government and practitioners will avoid the surprise element in setting approvals. The need to review and establish objective guidelines for reclamation certificates is noted.

Translating Concepts into Guidelines

The working rules within Alberta today have been established in three parts (Figure 1). The Land Surface Conservation and Reclamation Act of 1973 is the enabling legislation for reclamation throughout the plains, foothills and green zone. Other Acts, as shown, influence the technical aspects of the technical guidelines flowing from the Act. The Act is viewed by practitioners as reasonable legislation. Particularly well regarded are the provisions for the Land Conservation and Reclamation Council to include as members local field experts to act as 'eyes and ears'. The second part, the reclamation technical guidelines, which were first prepared in 1977, are considered to be too general, failing to provide sufficient definition of reclamation goals. The need for these guidelines is widely supported. Their revision is essential as a pre-requisite to establishing approvals which are the most specific area.

The decreasing importance of procedures and the increasing emphasis on techniques as we see the relationship of the Act, Guideline and Approvals is shown in Figure 2. The areas we must devote most attention to are at the Guideline procedure and Approval technique levels.

Developing such guidelines and approvals is the most appropriate avenue to promote sound reclamation practices within the Province. The question remains how can these guidelines and ultimately the approvals be adequately investigated, reviewed for all to understand and finally put in place? There has to-date, been considerable disagreement over the process and, too often, conflict between the regulated and the regulator. Renewed efforts on both sides are needed to bridge the gap

You have heard how the Land Reclamation Council and other Alberta Government departments responsible for land reclamation see the future. This is a bright future, and we are all going to be challenged by the technical and social aspects of our work. As members of society at large, we must establish realistic goals in reclamation matched with responsible and economic methods to reach those goals.

Long range planning by RRTAC to test reclamation methods, is to be applauded. As well operators throughout the Province are recognized for their significant contribution to planning and implementing reclamation programs that have become more costly and time consuming in the last 10 years. It is relevant at this time, two months away from the tenth anniversary of Royal Assent to the Land Surface Conservation and Reclamation Act, that a description of our future prospects as operators is in order. The views that I express are not mine alone, but have been gleaned from recent discussions with a broad range of experts within the resource industries and consulting businesses in Alberta.

I will first describe the three areas of the regulatory system that address reclamation and how these three areas are seen by operators to affect legislation and the definitions of acceptable reclamation.

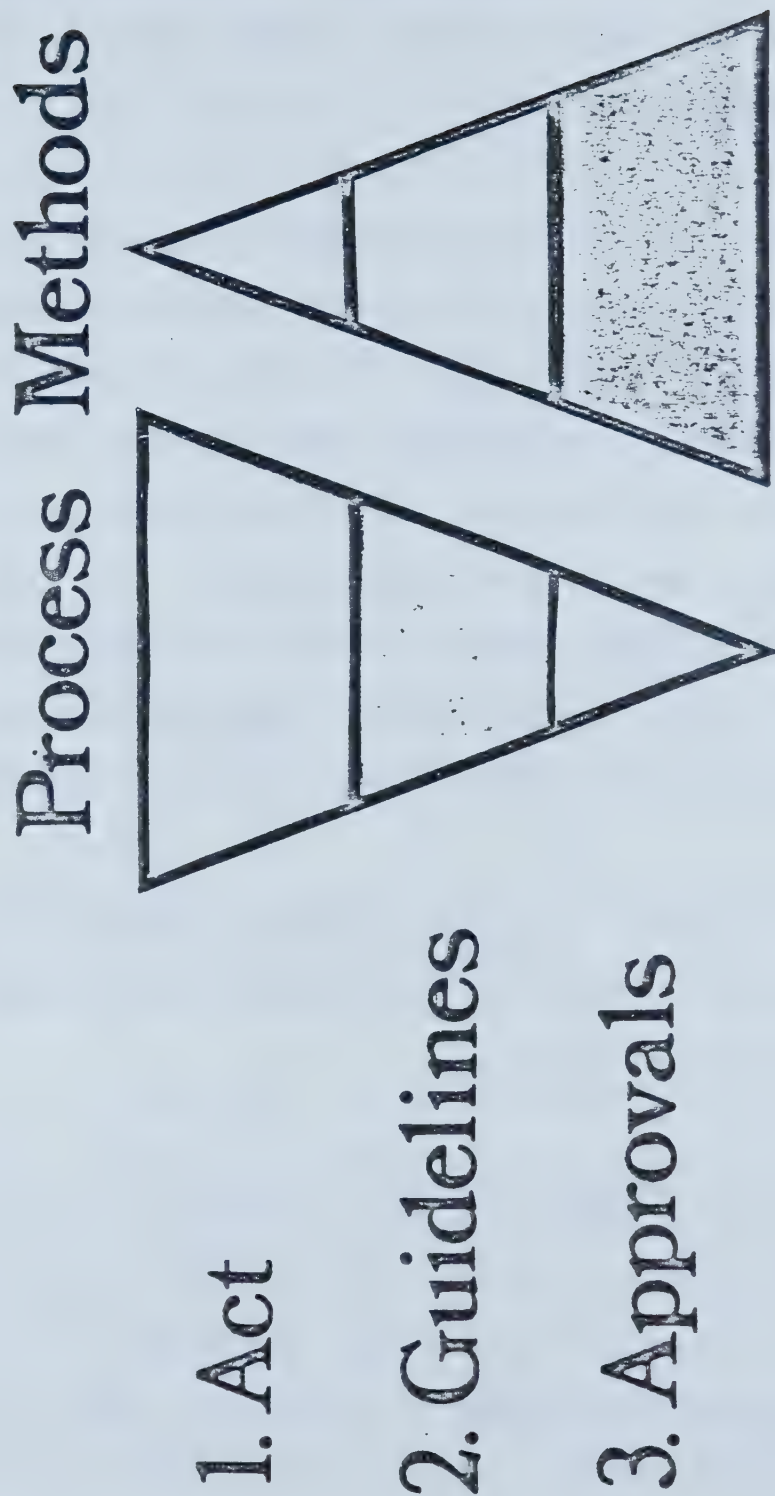
I will include some suggestions of what should be done to improve the track record to date and eliminate the potential for last minute changes, the surprise element.

FIGURE 1

EXISTING RECLAMATION LEGISLATION IN ALBERTA

1. LAND SURFACE CONSERVATION AND RECLAMATION ACT
CLEAN WATER ACT
WATER RESOURCES ACT
FORESTS ACT
FOREST AND PRAIRIE PROTECTION ACT
CLEAN AIR ACT
2. GUIDELINES FOR RECLAMATION OF LAND
3. APPROVALS:
EXPLORATION
DEVELOPMENT AND RECLAMATION
RECLAMATION CERTIFICATE

FIGURE 2
THE RELATIONSHIP OF LEGISLATIVE PROCESS AND PRACTICAL METHODS
TO THE THREE PARTS OF RECLAMATION LEGISLATION IN ALBERTA



between field practice and theoretical ideas. For example, if a specific guideline for disposal of ash, waste rock or coal partings by covering with 5 feet of soil is mutually agreed, last minute changes in approvals to increase the depth or require special liners in disposal areas is clearly unacceptable.

An example of the need to be specific is found in the Guidelines and the Coal Policy. Defining the potential of land after reclamation has not been adequately communicated. The words "productive", "useful to man", "desirable" and "capable" have all been used. The precise meaning has never been clear and in many cases, it has been difficult to tell whether each term was interchangeable. The important lesson we have learned from this example is that use of terms and definitions must be given a candid airing and an objective definition approved by operators and regulators before being formalized in legislation.

There are two steps. First the reclamation guidelines must be rewritten in a form which includes few generalizations and attempts to be specific and objective on most points.

Second, as the guidelines are being developed, they must be presented to a representative group from the operators responsible for actually doing the work. A multi-disciplinary group such as the Canadian Land Reclamation Association might be effective in pulling together differing interests within industry. Such a group could review the text of the draft document and discuss it with members of the Reclamation Council whose duties include enforcing the regulations. Following this exchange of written material and ideas, specific areas that require additional

research or investigation would be identified, the honing of definitions would continue and a specific time would be identified for testing and using the guidelines before further revisions.

Once the guidelines are defined, there must be a clear sense of purpose and willingness to cooperate among the different interest groups preparing the approvals from a regulatory point of view. Too often, there is delay in gaining approvals for licenses because of the myriad of interests running the gamut from archaeology to wildlife, often with differences of opinion on the interpretation and application of the guidelines.

For example, with the guidelines in place defining acceptable quality of soil, the standards cannot be changed late in the approval stage after considerable time and effort will have been spent on soil surveys, cost estimates and project design. Or to specify in approvals soil survey map scales that are not matched to the field where large earthmoving equipment is being used is clearly impractical.

There is no doubt that the Development and Reclamation Review Committee is accepted by everyone as the best forum for discussing those issues in approvals that affect practical aspects of each project. Most important in this context is the two way exchange of ideas before approvals are committed to paper. Local conditions at the project site will affect specific requirements and the methods to be used.

It is also important for the operator to be prepared with adequate detailed information. If sufficient time is planned by the operator,

mutually acceptable approvals can be written without last minute costly changes.

Technical Aspects of Approvals

I would now like to turn to the technical aspects of the approvals.

Reclamation is presently undergoing a substantial technical evolution. Evolution means change, and change cannot possibly be effective or successful unless there is sufficient amount of communication and definition of goals. In setting certain technical goals and objectives with very specific limits attached, we must not lose sight of the fact that we are charting future land use and land management strategies.

A responsible attitude to the general public, and the customer who must pay the price of resource management, is essential. The detailed requirements for each operation in the Province must have acceptable time frames and acceptable costs. Many of my colleagues have stressed the need to spend more time considering the economics of some technical decisions. This is not to suggest that only dollars will dictate the outcome of our objectives, but there should be far greater consideration given to the implications of cost in each operation. For example, if the final reclamation produces some land rated lower in quality than that which existed before disturbance, is the extra cost justified to replace equal quality? Or, a universal requirement for slopes of 10 degrees or less in the plains can often ignore the potential benefit of steeper slopes. As slope angle decreases, costs also increase with more earth-moving required.

With thoughtful evaluation, changes to the requirements for reclamation will certainly provide (1) a far better job in the end; (2) probably a less costly job; and (3) a far greater sense of mutual and satisfactory involvement in achieving the end result.

There is also the opportunity for surface disturbances to create new features with long term value.

I would like to conclude my comments on the technical aspects of the rules by mentioning the reclamation certificate. This approval is something of a mystery to companies responsible for large surface disturbances.

Industry representatives have difficulty understanding what the certificate inspection is for. For example, if the license conditions mutually approved by industry and government require replacement of 15 cm of topsoil, is this a feature of the certificate inspection? If all the conditions of the approval have been met, is the certificate granted, or are there further unwritten conditions that must be met? These types of questions need to be aired.

The Reclamation Council officers must be commended on their willingness to discuss technical aspects of the certificate. However, in the case of surface mines, the officers are not clear on what the inspection should be addressing and a great deal of uncertainty remains on the outcome of an approval application. In order to focus everyone's efforts, the production of land use plans coupled with capability measurements will describe the final objective. In common with the preparation of guide-

lines, a joint group of government and industry experts should prepare the specific purposes and measurement criteria for reclamation certificates.

I spoke earlier of communication. We already have at our fingertips three valuable communication tools that should be used to far greater effect than is presently the case. For example, the approval for a project prepared in draft form offers a starting point for discussion with the development proponent. Nobody pretends that these conditions are cast in stone, and during discussion there is ample opportunity for questions, reactions and reassessment. A compromise must often be reached for the conditions to be established in a timely fashion.

Once the approval is in place, the annual report becomes an excellent vehicle for those who do the work to reflect on their results and to solicit additional response. Both the annual report and the field meetings which are usually held in mid summer are excellent opportunities to resolve reclamation challenges cooperatively.

The third opportunity for increased communication is workshops such as those preceding and succeeding this morning's session. No one specific group has all the answers. No one practical application will solve everybody's problems. However, acknowledging that we do not have a solution may, in fact stimulate others to look for and assist in finding the right answers.

In reclamation throughout Canada and to some extent other countries, there has been a tendency to overdesign the system and to add rather

than subtract. While an optimist might hope for substantial reductions in the design criteria, the reality of the situation is that litigation is required in parts of the U.S. to resolve reclamation standards considered unreasonable. I don't believe the confrontation approach can be allowed to interfere with our goal of practical cooperation in Alberta.

The reclamation legislation in Alberta has three key sections, the Land Surface Conservation and Reclamation Act, the Reclamation Guidelines and Approvals. The Act provides an excellent framework. The Guidelines must be objective. A thorough revision of the Guidelines, to include a broad representative cross section of operators must be completed and the Canadian Land Reclamation Association could provide a valuable focal group to achieve this. When the Guidelines are prepared, long range research plans can be set, and short term technical decisions can be made. The guidelines should be given a formal revision date. Approvals must be the cornerstone of discussions with the D & R Committee, using established objective guidelines as support. Detailed criterion for reclamation certificates are needed.

The title to my presentation asked the question, "Is the cooperative spirit alive?" The answer is an emphatic yes!

PERCEPTIONS OF REALITY

M. Ross

Crows Nest Resources Limited

Calgary

The justification for a joint meeting of the Alberta Soil Science Workshop and the Alberta Chapter of the Canadian Land Reclamation Association is the growing appreciation by specialists that their contribution to society extends well beyond the confines of their own particular disciplines.

It must first be recognized that the art, or science, of reclamation is new to the Province of Alberta. In order to develop a reclamation technology appropriate for Alberta conditions, we cannot merely import successful reclamation technologies from other parts of the world. However, we can import the successful philosophy, a philosophy of planning, cooperation and coordination.

Returning to my title "Perceptions of Reality", attitude to reclamation is based on experience. In Alberta, this experience has been generated from an appreciation of mining and other industrial activities which occurred well before any legislated requirements for reclamation. This appreciation does not always reflect reality. There exists in Alberta lands which have been disturbed and which are back to full agricultural production. Lands also exist which are not back in production of any type and cannot, by any stretch of the imagination, be considered as

acceptable to any responsible individual associated with any aspect of land disturbance. Attitude to reclamation is based, to a large extent, on which of these lands are known. The latter lands, derelict lands, are now being reclaimed through joint efforts of the Alberta Government and Industry or by Government. The reclamation of these derelict lands is a small and diminishing area of activity.

Modern reclamation is now an activity associated with soil surveys, overburden assessments, hydrologic studies, vegetation surveys, statistically valid plant growth studies and an integrated development plan which includes reclamation as an ongoing component of the overall operation. These are conducted during the development and operations phases of industrial activity with Regulatory approvals integrated with the technical mine approvals.

Increasingly the application of soil science promotes an understanding of the soil and its responses to disturbances. This allows the opportunity for the planning of post disturbance reclamation and the integration of reclamation with the type and methods of disturbance. The occurrence of soil problems such as dryland salinity, irrigated land salinity, hardpan formation, solonetz formation, crust formation and organic matter degradation may occur naturally or may be induced by man's activities. Many of these problems are common to both agriculture and to industrial activity. It must be remembered that in both agriculture and industrial activity these do not always occur. However, at specific sites they do occur.

This is the reason for this joint session. We are here not to stress the differences among our respective disciplines but the common ground which exists among them. In some areas of Alberta the application of existing agriculture and forestry technology is sufficient to achieve satisfactory reclamation. In these instances disturbance is either minimal, compatible with existing land use, or occurring where reclamation capability is high. In other areas this is not so, and it is in these areas where the combined efforts of those involved in reclamation activities and in soils research is necessary. The information conveyed by data points, which can be determined in conditions occurring in mining, but which may be uncommon in agriculture and forestry, may serve to extend the knowledge of the relationships in specific physical or chemical problems and eventually be applied not only for reclamation but also for agriculture and forestry.

It is essential that a coordinated approach be adopted, an approach involving contributions from industry, the community, and government; an approach which is rational and which will minimize long term disturbance to the land. By this the public is best served.

Ideally, land disturbance for industrial use should be regarded as a temporary alienation of the land from a particular long term use; whether that use be agriculture, forestry or wild land. In this regard agriculture, forestry and wild land use are also land disturbances with time scales significantly longer than those for industrial activities. All types of land disturbance affect biological, biophysical and biochemical processes through short term, long term and cumulative effects.

Those involved in agriculture, forestry, wild land management or reclamation following industrial activity should be cognizant of the latter fact.

In conclusion, it must be stressed that objectivity is essential. Philosophical blinkers must be removed in order that any program which addresses reclamation should be based on reality, not perceptions of reality.

THE IMPACTS OF PIPELINES ON AGRICULTURAL LANDS IN ALBERTA

L.C. Marciak and J.C. Hermans¹

Alberta has been blessed with vast reserves of oil and gas important to both the domestic and industrial well being in the country.

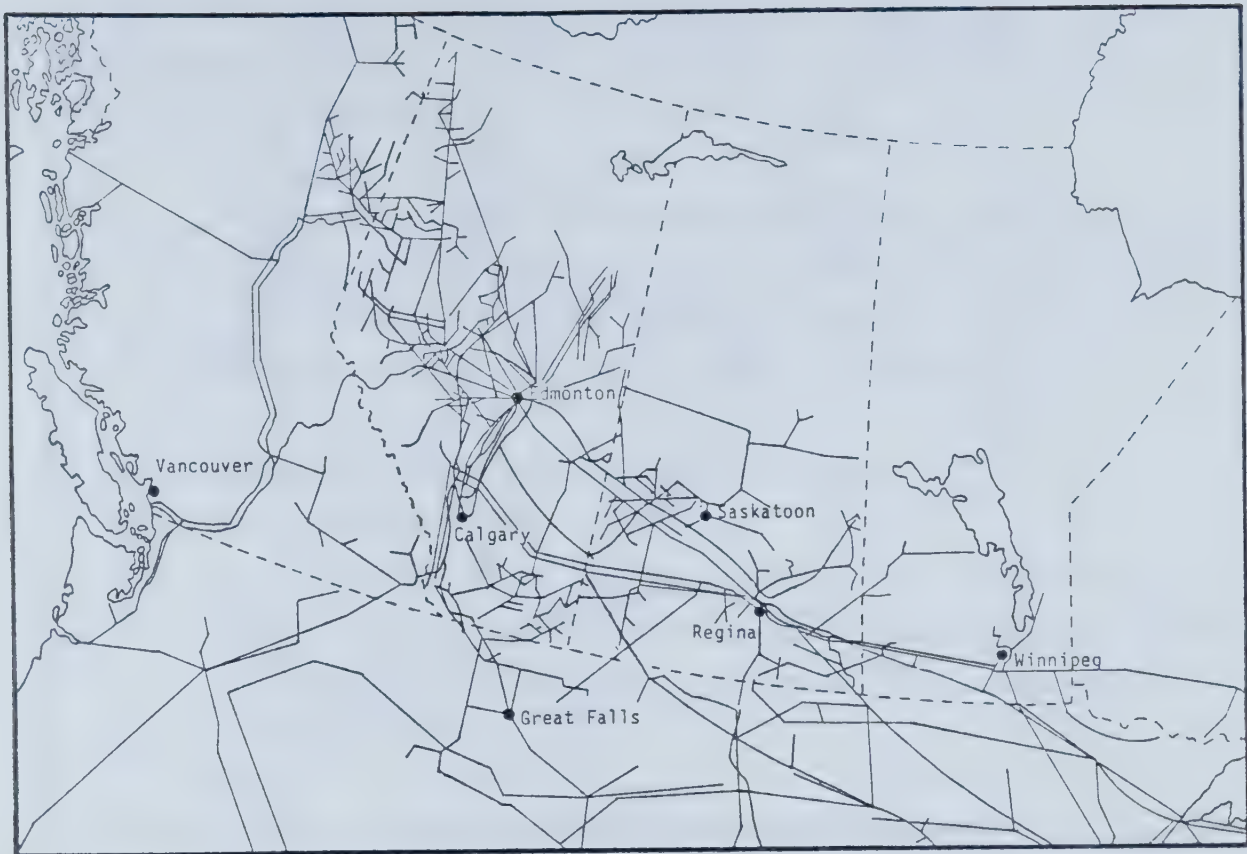
Unfortunately the energy reserves and the industrial developments are not located together and therefore pipelines have become an integral part of energy and industrial development. This paper intends to provide the reader with a basic understanding of pipeline construction procedures and their potential impacts on agricultural lands.

Pipelines have proved to be an efficient and economic means of transporting liquid and gaseous materials between source, refining or processing and market. In North America the distance between energy resources and major markets is great, emphasizing the importance of pipelines in transporting energy. The flow is predominantly from northwest to southeast, from the major oil and gas field to the major centers of industry and population (Map 1).

ERCB statistics show that there are approximately 180 208 km of pipeline in Alberta (Table I). They range in size from main oil and gas lines to small distribution and flow lines (Map II). Some of the largest diameter and longest pipeline projects in the world have crossed or originated in Alberta. For example, Edmonton is the "kick-off" point for the longest crude oil pipeline system in the world. The Interprovincial Pipe Line Company's installation spans 2 840 km from Edmonton, Alberta, to Buffalo, New York, maintaining a flow of 37 640 000 litres per day (McWirter, 1982). The Alaska Highway Gas Pipeline Project has a potential to surpass the Interprovincial Pipeline in length and width. If completed, the Foothills Pipe Lines Ltd. installation of 1 067 mm and 1 422 mm diameter pipe will span 7 664 km of which 1 311 km crosses Alberta (McWirter, 1982; Nova, 1981). The Alberta portion has been completed and is operational.

¹Alberta Agriculture

Map I Pipeline Routes in Western Canada



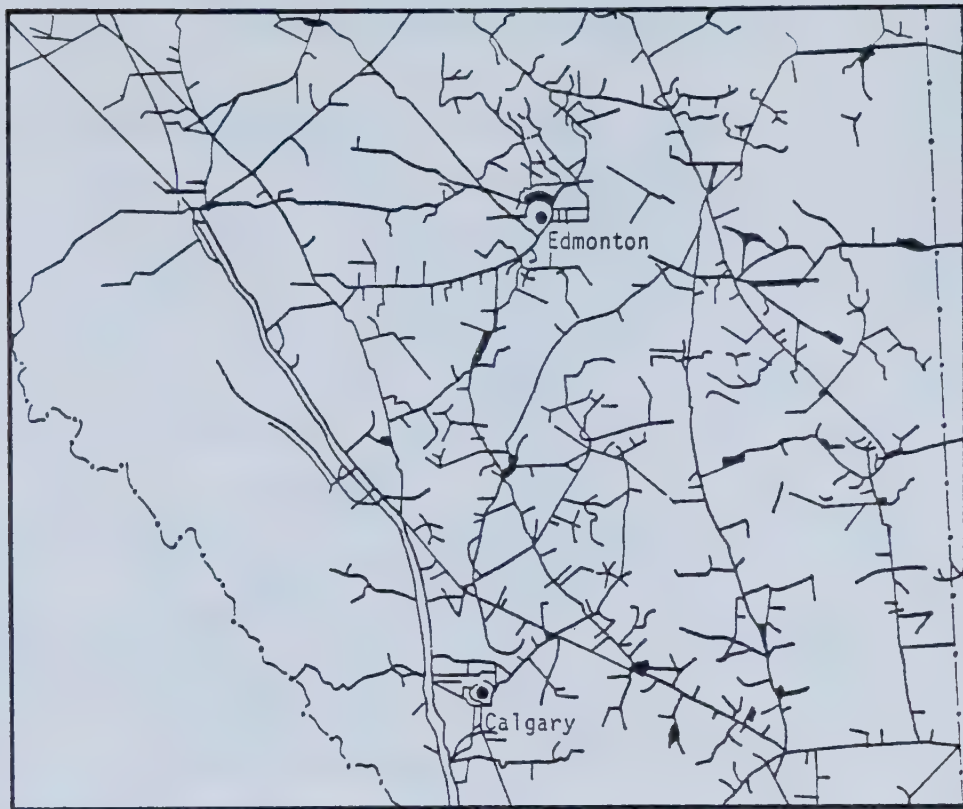
(Behr and Davenport, 1981)

Table 1: Length of Pipeline by Function in Alberta, July 1981

Type of Pipeline	Length of Pipeline	
	(km)	% total
Main oil lines	12 307	6.8
Secondary (gathering) oil lines	8 512	4.7
Main gas lines	21 556	11.9
Secondary gas lines	38 476	21.3
Alaska Highway (NEB)	1 931	1.1
Secondary lines water and other substances	11 271	6.3
Distribution lines	69 831	38.7
Flow lines	16 354	9.2
TOTAL	180 208	100

adapted from Webb, 1982

Map II Pipelines in Central Alberta



(Oilweek Pipeline Wall Map 1982-83, Algoma Steel Corp. Ltd.)

Alberta has 12 525 755 hectares of improved lands that support 61,130 farms, the backbone of its agricultural industry (Agricultural Statistics Yearbook, 1981).

Studying a pipeline map of Alberta one finds that the majority of pipelines are located on these agricultural lands. The potential for impacts on agriculture is therefore inevitable.

Legislation with regard to land disturbance and pipeline construction is defined in Chapter 34 of the Land Surface Conservation and Reclamation Act in the Revised Statutes of Alberta. Section 1(p) defines pipeline as follows:

1. "a pipe for the transmission of any substance and installations in connection therewith;
2. a sewer or sewage system and installations in connection therewith."

Pipelines have been further defined by the size of pipe and length of system in the Regulated Oil and Gas Pipeline Surface Operation Regulations under the Land Surface Conservation and Reclamation Act. Section 1 (L) states:

1. "a pipeline as defined in the Pipeline Act (1975) and to which that Act applies, that is 150 mm or more in diameter and 16 km or more in length and includes an access road, railway or telecommunications line in connection therewith it or,
2. a pipeline for which there is in force
 - A. a certificate, or
 - B. an order exempting the pipeline from a certificate, issued or made by the National Energy Board Act (Canada) and any installations or access roads in connection therewith."

Therefore, because of the diameter and size requirements, only about 1% of the total applications and 3% of the total length of all pipelines are regulated (Bratton, 1983). Thus reclamation on most pipelines is left to the pipeline companies and is usually negotiated with the individual farmers. The remainder of this paper is intended to be only a general summary of some of the impacts that a farmer may experience as a result of a pipeline crossing his land.

When considering the impacts of pipelining we are usually concerned only with the narrow one meter wide area directly over the trench. Pipeline construction, however, may impact an area that varies from 10-40 m wide, depending upon the size of the pipe and depth at which it is installed. This affected area is referred to as the Right-Of-Way (ROW), which may be subdivided into three main components; working side, trench, and spoil side (Figures I and II).

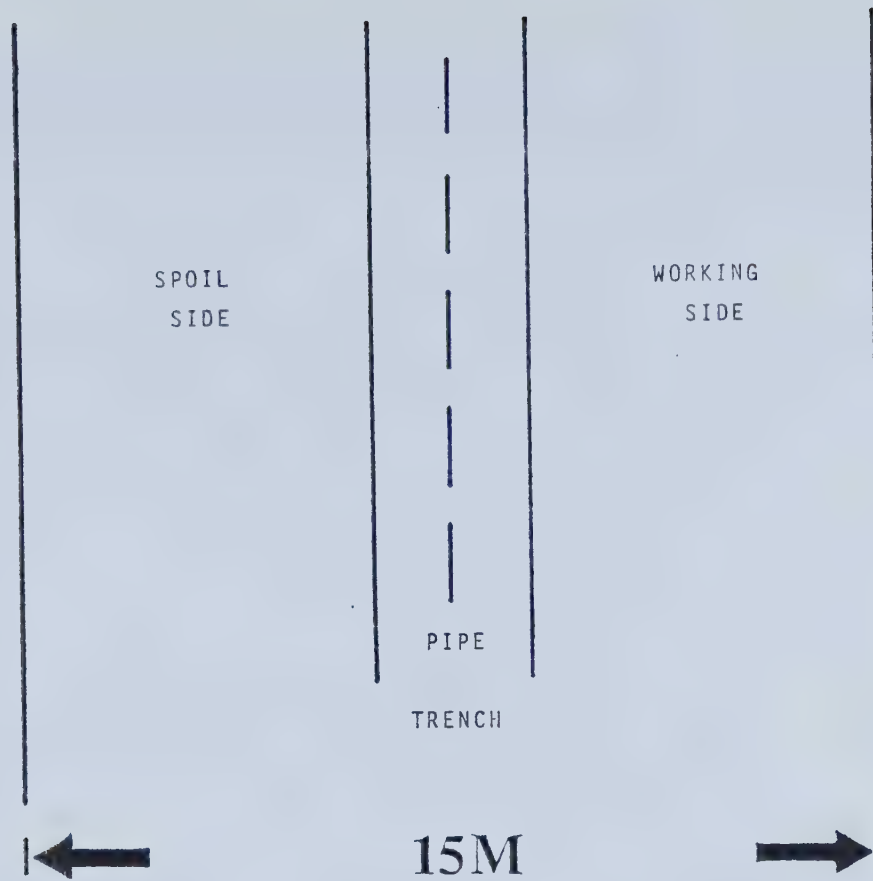


Figure I Pipeline Right-of-Way

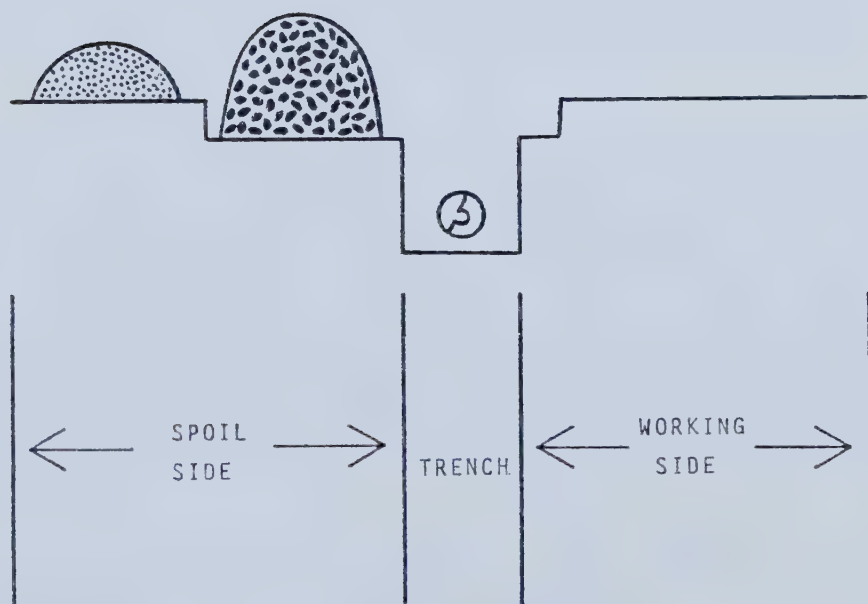


Figure II Cross Section of Pipeline Right-of-Way

The impacts on the different areas of the right-of-way vary due to the nature of the different operations involved. Some of the effects are as follows:

1. Working Side

The working side as the name implies is the area where the equipment travels to construct the line. Construction procedures such as pipe stringing, welding, pipe bending and testing all take place on the working side. As a result of the traffic involved in these operations, the working side is often susceptible to compaction and erosion.

2. Trench

The trench area is the part of the ROW most affected by disturbance. The trench is usually excavated by a ditcher or in some cases a back-hoe. Once the pipe is laid in the trench, the spoil material is returned to the trench. The backfilled material may be compacted by heavy equipment, however in most cases there is a slight berm left over the trench area which may disappear in time. Problems usually occur when topsoil and subsoil are not salvaged and replaced properly resulting in mixing or loss of topsoil.

3. Spoil Side

The spoil side is the part of the ROW where topsoil and the subsoil materials are stored during the construction phase. This area may be impacted when subsoil materials are left on the surface. The extent of the impact will depend on the amount and quality of the subsoil mixed with the topsoil. There may also be some compaction of the spoil side depending upon the site conditions and the kind of equipment used to backfill and replace the topsoil.

Pipelines may have either a positive or negative effect on crop growth. However, even an increase in productivity may prove to be a disadvantage for the farmer. For example, additional available moisture due to

loosening of the soil in the trench area may result in increased production of some cereal crops. Because of the improved growing conditions the crop may mature later and still be green when the rest of the field is ready to harvest. Perhaps we should therefore be concerned about the change in the growth pattern of the crop, not just whether or not there is a loss in production.

A decrease in yield may result from a number of factors. Failure to replace the topsoil or mixing of the topsoil with subsoil materials may result in poor seedbed conditions and hence germination problems. These problems are magnified if the materials left on the surface are highly sodic or contain high levels of soluble salts. Soil compaction may also present a problem on some sites, particularly if construction occurred under wet conditions. Restricted root and moisture penetration may result in decreased yields for at least several years on some sites. A decrease in crop response may also reflect the lower nutrient status of the soil. This is again usually associated with loss or mixing of the topsoil.

Pipeline construction may in some instances result in an increase in yield, particularly over the trench. The "deep plowing" effect which occurs during the digging and filling of the trench is often noticed on solonchic soils (DeJong, 1980; DeJong & Button, 1973). Crops may respond dramatically to the disruption and mixing of the sodic hardpan with the lime-salt layers below. Even in soils without a hardpan, the physical loosening of the soil will often improve root and moisture penetration and result in at least temporarily improved growth. Some pipelines may also warm the soil resulting in earlier germination of cereal crops and faster growth of forage crops in the spring. If moisture is limited, however dessication may also occur resulting in the loss of productivity, particularly with forage crops.

Unless care is taken in proper design and construction, pipelining may also increase the erosion hazard. Pulverization of the soil during stripping and replacement operations may leave the soil more prone to

erosion by both wind and water. The berm, usually left over the trench to allow for subsidence, may become a barrier and obstruct normal surface drainage patterns. Unless preventive measures are taken, water flow may then become concentrated along the line resulting in erosion. Perhaps because it is higher and dryer the berm also attracts cattle in pasture lands. Trails worn by cattle along pipelines are common and may become deeply channeled during runoff.

Careful planning can minimize most of the problems that may be encountered once the pipelines are installed. For example, allowance for additional cover should be considered in highly erodable soils or in areas of Solonchic soils that may be considered for deep plowing. Lands that may require surface or subsurface drainage need special attention in that surface ditches or subsurface tiles must be installed at a depth similar to that of the pipe. Delivery systems in irrigated areas present similar problems, again emphasizing the need for proper planning and implementation.

Pipelines do present a significant impact on agricultural lands in Alberta. While some of the impacts are minimal and short term, others are more severe and long lasting. Most of the impacts however could be minimized or eliminated with careful planning and implementation of the appropriate reclamation procedures.

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SOIL HANDLING ASPECTS OF COAL MINE RECLAMATION ON AGRICULTURAL LANDS

R.J. Logan, P. Ag.¹

ABSTRACT

Successful reclamation of agricultural lands disturbed during coal mining requires an effective soil handling program to return a suitable root zone. The development requirements for a handling program specific to each mine site are highlighted. Consideration is given to inventory of existing soil and overburden conditions, current reclamation technology, and practical and economic limitations of the mining operation.

INTRODUCTION

Soil handling has become a significant, integrated part and cost of coal mining on agricultural lands in Alberta. The basic objective of soil handling as set out in provincial policy and reclamation guidelines is to ensure that the reclaimed lands have a root zone soil which will be at least as productive as the soil which existed prior to disturbance. Such programs are a requirement for government approval of mine development.

To attain this objective, a soil handling program must be developed based on evaluation of site conditions (existing and anticipated post-mining), current reclamation technology and practical and economic considerations of the mining operation. These aspects of soil handling are briefly discussed in this paper.

SITE INVENTORY

What are the soil handling requirements to successfully reclaim a mine site? The answer will be specific to each site, requiring evaluation of site soil and overburden conditions as a crucial first step towards developing a soil handling plan.

Coal is found under a variety of soil landscapes in the Alberta plains, ranging from prime farmland to lands of little value to agriculture (Hermans and Goettel, 1980). Soil handling requirements for reclamation however relate not simply to existing soil conditions, but to characteristics of the total

¹ Reclamation Coordinator, Luscar Ltd., Edmonton.

overburden, particularly as these relate to future mine spoil quality. Characterizing the soil and overburden profile is a prerequisite to determining reclamation requirements and should be conducted as early as possible in the project development. When tied to initial exploration programs, benefits arise from early awareness of reclamation requirements, better correlation of geological information as well as cost savings on equipment and land access.

Of particular importance at most plains coal fields are levels of salinity, sodicity and saturation percentage (particularly as an indicator of clay content and mineralogy) in overburden materials (Figure 1). Unsuitable levels are often associated with the soft bedrock strata in which the coal is found. It is important to evaluate the complete overburden as materials other than the pre-mining root zone may be suitable for soil reconstruction, perhaps at lower handling costs (Krogman and MacKay, 1980). Guides are available to assist in evaluating material suitability for reclamation (Schafer, 1979; Alta. Agric., 1981). To assess overburden suitability as root zone materials, it is useful to compare all materials to the existing subsoil using the same criteria (for example Table 6 in Alta. Agric., 1981).

Differences in overburden characteristics can have a large impact on soil handling methods and costs. For example, overburden at the Diplomat Mine near Forestburg produces a high quality mine spoil as suitable as the pre-mining subsoil. Here, prime farmland (dominantly Thin Black Chernozems, C.L.I. Class 2) is reclaimed by selective handling of less than 0.3 m (1 foot) of topsoil (A horizon). Meanwhile at the Paintearth Mine 10 km (6 miles) south, reclamation plans for similar soils require handling of 1.5 m (5 feet) of soil by scrapers at considerable additional cost due to unsuitable spoil quality.

Beyond determining amounts of suitable material available and anticipating future spoil conditions the inventory should provide detailed information on the distribution of suitable materials over the mine site (Figure 2). A mapping scale of at least 1:10,000 is recommended (Alta. Agri., 1981; Patterson, 1976). Soil distribution is an important consideration in handling programs and there are economic and practical limitations on the degree of soil redistribution during reclamation.

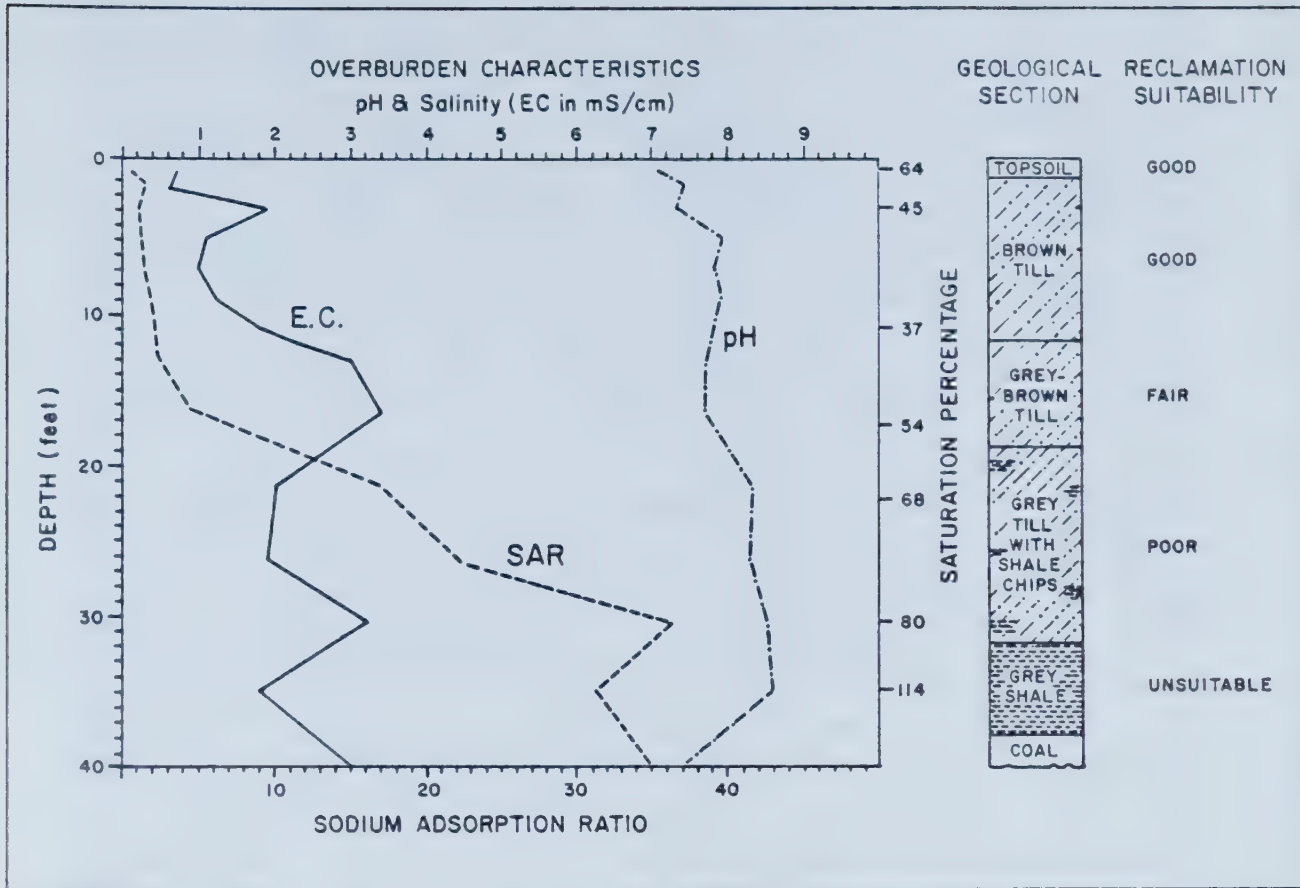


FIGURE 1: Characteristics of the total overburden profile must be considered in evaluating soil handling requirements for a coal mine.

SOIL THICKNESS REQUIREMENTS

From the site inventory, the characteristics of the soils in relation to hydrological conditions and landscape position (Wallenhaupt and Richardson, 1982) give indications of soil thickness requirements for reclamation. The thickness of the solum (A plus B horizons), the depth to which roots are plentiful or the depth to salt accumulation layers in the native soils are indicators of the effective rooting zone depth. This depth will vary from less than 0.45 m (1.5 feet) in the drier Brown Soil Zone to 1.2 m (4 feet) in the Black Soil Zone.

At some sites, suitable spoil conditions may reduce the soil handling requirement while at other locations complete root zone replacement may be necessary due to unsuitable spoil conditions. Landscape and hydrological aspects of the reclaimed lands should also be considered in determining soil replacement plans.

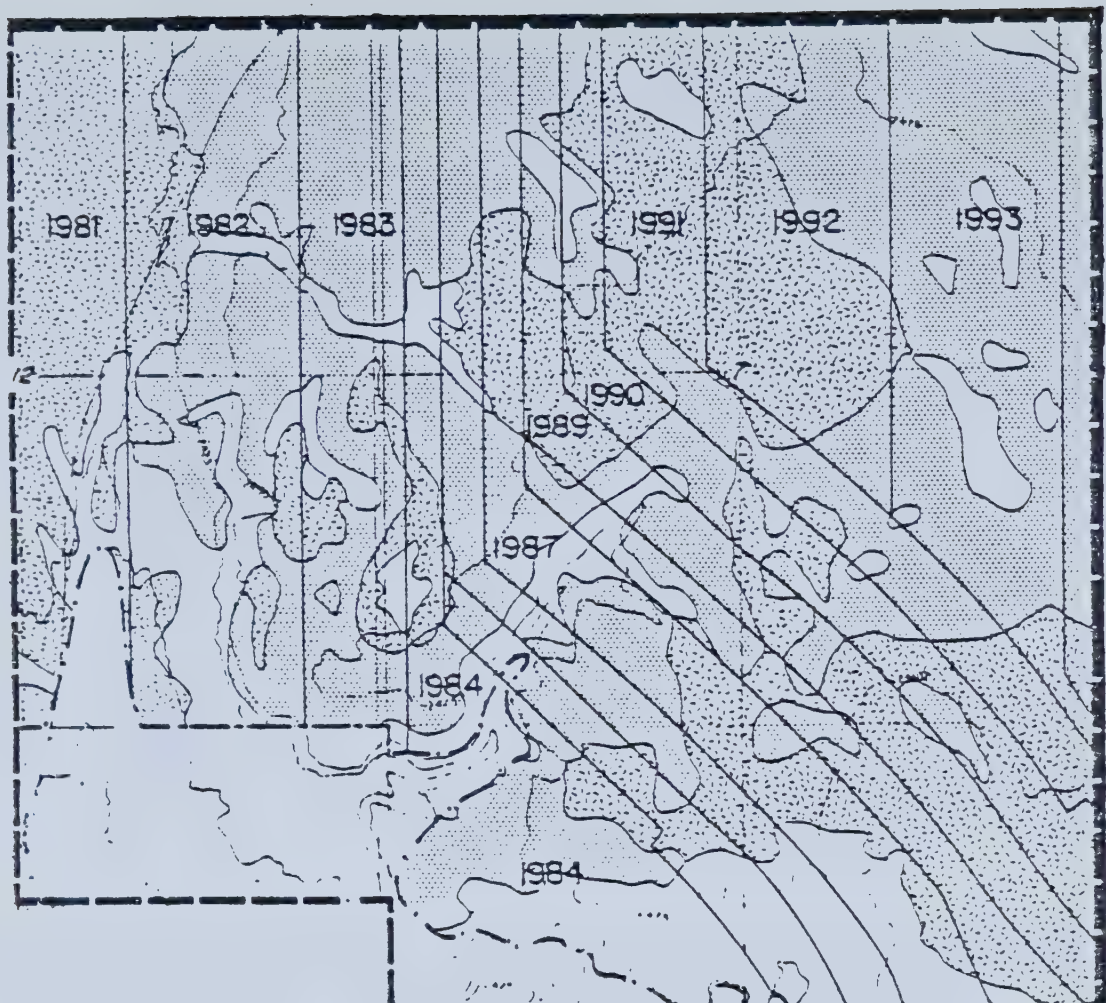


FIGURE 2: Distribution of soil (here Deep, Shallow and No Soil Zones are shown) in relation to yearly soil stripping prior to coal mining is an important handling consideration (3.4 inches per mile).

Reclamation research has indicated that in the case of unsuitable sodic-clay spoils, the replaced root zone should be protected from degradation by upward salt movement. Studies have indicated that one mechanism for salt movement is diffusion, driven by a gradient in salt concentration between spoil and replaced soil and affecting up to 0.3 m (1 foot) of soil (Merrill et al, 1982). A second mechanism is capillary rise of saline water from a watertable re-established in the spoil or perched at the soil/spoil interface. The latter has not been found by researchers (Power et al, 1981), but these soil moisture and hydrological aspects are receiving continued attention (ARS/NDSU 1979; Moran et al, 1982).

Further findings of reclamation research have indicated the advantages of separate handling of topsoil (Ah horizon) from subsoil in most instances due to the special qualities of topsoil (Schuman and Power, 1981). Investigations have also shown that while crop yields increase with increasing soil thickness to about 1.5 m (5 feet) over sodic-clay spoil, yields within 90 percent of the maximum may be obtained with about 0.9 m (3 feet) of soil (Power et al, 1981). As Figure 3 indicates, reclamation efforts face "diminishing returns" (i.e., the last few percentages of yield come at a high cost). Figure 3 also points out that reclamation is not an "all or nothing" operation, in that reduced soil thickness means less productivity, not no productivity. Examples are available where less than 0.15 m (0.5 foot) of topsoil has sustained a vegetative cover over sodic spoil. On the other hand, the productivity of some soils may be increased by handling techniques which, for example, simulate the "deep plowing" of Solonetzic soils (Logan and Egglestone, 1982).

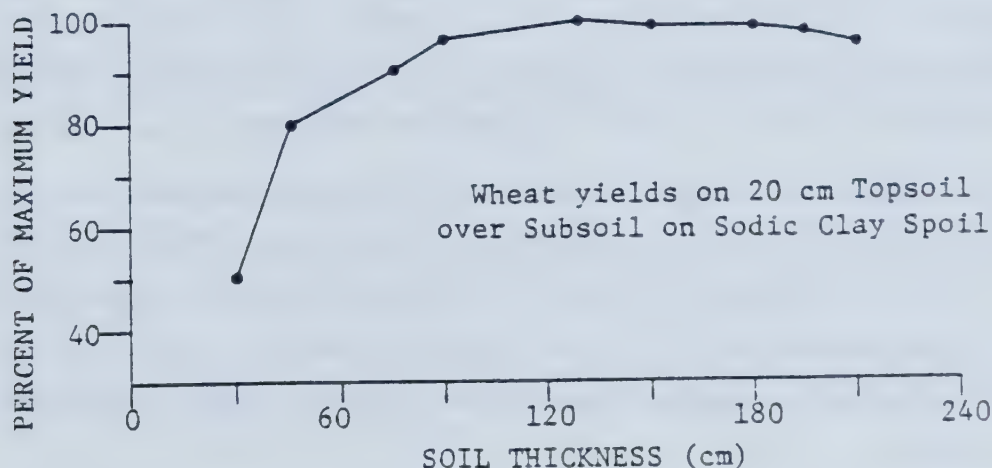


FIGURE 3: Diminishing returns on reclamation efforts
(Data from Power et al, 1981)

PRACTICAL CONSIDERATIONS

While inventory methods and soil quality guidelines can precisely define suitable horizons or materials for reclamation purposes, this information must be transformed into an efficient, practical plan which will meet reclamation objectives. When considering the selective handling of various soil materials the operational limitations of equipment must be recognized. For example, motor scrapers are the most common and precise "tool" used for soil handling, but comparison of selectively handled topsoil on reclaimed land with undisturbed topsoil in Table 1 shows the limitations of this equipment.

TABLE 1: Comparison of "Topsoil" from Cultivated Unmined and Reclaimed Lands at the Diplomat Mine, Forestburg, Alberta (Thin Black Soil Zone)

LOCATION	TOPSOIL DEPTH (CM)	PH	E.C. (MS/CM)	O.M. (%)	TEXTURE	OVERALL SUITABILITY RATING
<u>UNMINED</u>						
RANGE (4 SITES)	10-15	5.5-6.0	0.1-0.3	4.1-6.1	LOAM	
SUITABILITY	F	F	G	G	G	F
<u>RECLAIMED</u>						
RANGE (9 SITES)	10-15	6.2-7.1	0.3-1.0	1.9-3.6	CLAY	
SUITABILITY	F	F-G	G	F-G	G	F

Some subsoil material is mixed with the topsoil during pre-stripping operations and again during replacement. The result is a material with different properties, although the overall suitability may be the same.

Similarly, an additional "lift" or separation of soil materials adds greatly to the complexity of handling plans and operations. Therefore, it is necessary to carefully weigh the benefits against whether reclamation objectives would be compromised without such an undertaking. Selective soil handling is costly and can be a significant item in the overall operation of a mine (Chopiuk, 1982).

While soils and soil distribution are quite diverse in the natural landscape (Figure 2), soil handling programs tend to "homogenize" and re-distribute soils in the reclaimed landscape. There is however an economic limit as to the extent of re-distribution of soils. This basically requires handling plans to be developed using the soil materials readily at hand within an operating area of the mine. Studies have shown that soils on reclaimed lands are overall less variable than natural soils, although over short distances their variability may be greater (Schafer, 1982). As a result, reclaimed lands tend towards an average quality rather than the extremes which may have existed previously. This may have advantages in terms of uniformity of land units and farm management practices.

CONCLUSION

Soil handling has recently become a significant part of coal mining operations. Input from soils professionals, mine planning engineers and mine operators is necessary to develop an integrated, efficient and workable program to meet reclamation objectives. Such programs are best developed specific to each site, based on a soil and overburden inventory, current reclamation technology, and practical and economic considerations of the mining operation.

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WEATHERING CHARACTERISTICS OF FLY ASH AND THEIR IMPLICATIONS
TO SOIL AMENDMENTS

C.J. Warren and M.J. Dudas¹

ABSTRACT

Fly ash is a by-product of coal-fired power plants which may be used as an ameliorant for certain soils. Beneficial effects derived from applying fly ash to soil when used as a liming material, as an ameliorant for some sodic soils or as a source of plant nutrients may be offset by the release of undesirably large quantities of other elements of environmental concern. The weathering behaviour of fly ash and the release pattern of the various constituent elements are discussed and related to potential benefits and problems resulting from the application of fly ash to soil.

INTRODUCTION

Modern coal-fired power plants produced vast quantities of coal ashes. Fly ash is the finely divided material entrained and removed from the flue gases of pulverized coal burning thermal electric power plants. Fly ash accounts for most (60 - 80%) of the total ash produced in coal-fired power plants. The use and disposal of fly ash is therefore an intricate part of coal-fired power plant management.

At present, most of the fly ash produced by power plants is not utilized and is considered a waste material. In 1978, Alberta produced 1.26 million tonnes of fly ash, but utilized only 159,000 tonnes or 12.7% of that produced (Joshi 1981). Most of the fly ash produced in Alberta and in North America is disposed of as landfill, mine refill or surface deposited.

¹Graduate Student and Associate Professor of Soil Science
respectively, Department of Soil Science, University of Alberta.

Information on the weathering characteristics of fly ash provides the basis for an assessment of the potential benefits and hazards associated with the use of fly ash as a soil additive. Several studies have been conducted in this Department of Soil Science and elsewhere which deal with the weathering behaviour and chemical properties of fly ash. This report outlines the available information on weathering characteristics of fly ash as they may relate to environmental quality and use of fly ash in soil amendment schemes.

FLY ASH WEATHERING

Unweathered fly ash is primarily made up of small spherical particles composed essentially of impure aluminosilicate glass. The particle size of spheres range from less than 2 μm to 100 μm diameter. The oxides of Si, Al, Fe and Ca usually comprise more than 90% of the ash with the remainder consisting of the oxides of Na, K, Mg and Ti. Fly ash also contains a host of trace elements many of which occur at elevated concentrations as compared to average lithospheric abundances. Additionally, some elements are heterogeneously distributed within ash particles and display surface predominance.

The initial weathering of western Canadian fly ashes is dominated by hydrolysis and dissolution of constituents concentrated on particle surfaces. Of the major constituents in fly ash, Ca and Mg appear to be the most highly concentrated on surfaces of ash particles. Once in contact with water the oxides of these two elements quickly hydrolyze. Subsequent dissociation of the strong base, generated by the hydrolysis reaction, results in the production of large quantities of dissolved Ca and extreme alkalinity (pH=12) according to the reaction:



The alkaline buffering capacity of fly ash is generally proportional to its CaO content.

MgO also occurs in fly ash but is present in much smaller quantities than Ca and reacts differently. The MgO hydrolysis product, $\text{Mg}(\text{OH})_2$, is insoluble under strong alkaline conditions. $\text{Mg}(\text{OH})_2$, formed during the early stages of weathering remains insoluble until much of the CaO has been dissolved and removed through leaching. Once the solution pH drops

below 9.0, the solubility of Mg increases. Mg may contribute to a second alkaline buffering region just below pH 9, however, Alberta ashes do not appear to contain substantial quantities of Mg to generate such a region. Small quantities of Ca and Mg may also occur on particle surfaces as soluble salts, such as sulfates and carbonates. These also quickly dissolve and contribute to solution concentrations during initial weathering stages, however, ionic levels are mainly controlled through the dissolution of the oxide and hydroxide phases.

Two additional elements which are also dissolved in significant quantities at the onset of weathering are Na and K. These elements are also surface concentrated, but not to the extent of Ca and Mg. With progressive weathering, much of the Ca and Mg are dissolved, while dissolution of Na and K proceeds at a much slower rate. Indeed, K and to some extent Na become negatively enriched in the solid ash residue as weathering removes the more soluble Ca compounds. The initial release of high levels of Na and K is likely due to the dissolution of soluble salts of these elements, such as Na_2SO_4 and K_2SO_4 , located on particle surfaces.

Fe and Al do not dissolve in early weathering stages when solution pH values are buffered in extreme alkaline ranges. Dissolution begins only after Ca has been removed and the solution pH value drops well into the acid range (below 5.0). Small amounts of Al may be solubilized under extreme alkaline conditions due to co-dissolution with Ca.

Small amounts of Si are released during the dissolution of Ca in some ashes. Dissolution in the acid range is paralleled by the release of Al from the glass matrix. Slow precipitation rates allow dissolved Si to reach supersaturation when pH values are acidic.

Large quantities of boron and some other trace elements, including heavy metals, are also dissolved from fly ash. Total contents range from 100 - 800 $\mu\text{g/g}$ in fly ashes derived from bituminous coals. Up to 50% of the boron found in some midwestern and western United States fly ashes was reported to be soluble in water (Cox et al. 1978). Dudas (1981) showed 77% of the total boron (480 $\mu\text{g/g}$) in an Alberta fly ash could be released by leaching only with distilled water.

SOIL AMENDMENT IMPLICATIONS

The weathering characteristics of western Canadian fly ashes suggests the material could be potentially useful as an ameliorant for certain Alberta soils. High alkalinity, generated through the hydrolysis of CaO and MgO, indicates the potential for neutralization of acidity. Solubilization of large quantities of Ca is a characteristic which indicates potential as an ameliorant for some sodic soils. Weathering and release of some elements beneficial to plant growth might also prove to be a useful characteristic of this material.

Western Canadian fly ashes may serve as a partial substitute for agricultural limestone. Phung and coworkers (1978) found that fly ash containing only 6.4% CaO was nearly one-fifth as efficient as dolomitic limestone at neutralizing acidity. Most Alberta ashes generally contain more than 10% CaO. Since liming capability is directly proportional to CaO content, Alberta ashes should be worthwhile liming agents.

Amelioration of sodic soils and sodic mine spoils with fly ash is contingent on the solution characteristics, especially soluble Ca:Na levels, generated by the ash. Although weathering of fly ash results in an initial release of some Na, SAR values tend to be low. For example, dissolution of a typical Alberta fly ash produces SAR values of less than one (Dudas 1981). The slow dissolution of Na from the glass matrix and rapid dissolution of CaO accounts for the favorable SAR conditions.

Fly ash appears to have only limited potential as a supplier of plant nutrients. Large quantities of Ca and Mg, released during weathering, would be available for plant uptake. Application of fly ash has been reported to alleviate boron deficiency in alfalfa (high boron requiring) on boron deficient soils (Plank and Martens 1974). Fly ash sulfur has been shown to be as available as gypsum-S on sulfur deficient soils. Fly ash has been shown capable of supplying less than 40% of its total K content to corn (Martens et al. 1970). This limited availability occurs because most of the K in fly ash is associated with the slowly weatherable glassy matrix. K uptake might also be influenced by the inhibiting effect of excess Mg supplied by some ashes. Most other plant nutrients found in fly ash tend to occur in low concentrations and application of high rates of fly ash would be necessary to alleviate soil deficiencies.

Fly ash seems better suited as a supplemental source of plant nutrients. Certain Alberta soils, such as the Gray Luvisols, contain marginally sufficient levels of certain micronutrients (Dudas and Pawluk 1977). Application of fly ash, primarily to rectify acidity in these soils, may also incidentally improve micronutrient levels.

The most noteworthy problem associated with land application of fly ash is associated with boron, although there is some concern with heavy metals and arsenic. Plant toxicity commonly occurs when hot water soluble boron levels in soil exceed 5ppm. Solubilization of large quantities of boron from fly ash is not uncommon and usually accounts for most of the phytotoxic action observed for soils receiving large application rates of fly ash. High rates of application may also elevate Mo and Se levels in soil which, in turn, can increase levels in vegetation and feed-stuffs and become toxic to animals (Doran and Martens 1972; Stoewsand et al. 1978).

Use of fly ash may also affect the availability of soil borne nutrients. For example, deficiency of Zn may be induced through increased pH resulting from ash addition. Decline in the availability of soil phosphorous, mainly due to precipitation under strong alkaline conditions and high Ca concentrations, commonly accompanies amendment with fly ash (Phung et al. 1978).

In conclusion, considerations which govern the use of any agricultural chemical, such as herbicides, also apply to the use of fly ash as a soil additive. Benefits may occur in its use as a soil ameliorant but these must be weighed against potential detriments.

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A REVIEW AND EVALUATION OF
AGRICULTURAL DRAINAGE IN ALBERTA

D. W. Broadfoot,¹ M.Sc.

ABSTRACT

In 1982, a study was carried out by the author, commissioned by the Alberta Drainage Branch to assess the state-of-the-art of Subsurface Drainage Research and Practices in Alberta, and to recommend where further research and extension work is needed. Data were gathered through a literature search and a series of interviews with key individuals. Some of the significant conclusions reached in the study include:

- a) there is a diversity of opinion regarding the use of subsurface drainage as a reclamation tool, especially in dryland areas,
- b) there is a need to determine and demonstrate to the farming community the value and cost-effectiveness of subsurface drainage as a reclamation tool, for both dryland and irrigated areas,
- c) there is a diversity of practices among those engaged in subsurface drainage, with two main schools of thought regarding investigation and design procedures. One school advocates applying rules of thumb to "typical" areas, the other school advocates treating each site as unique,
- d) more coordination and communication is required among government agencies and among those involved in subsurface drainage research and practice,
- e) research projects are needed that will determine: the economic viability of on-farm subsurface drainage; the potential longterm adverse environmental impacts of subsurface drainage effluent, including mitigative measures; the applicability of existing out-of-province data to subsurface drainage practices in Alberta; the interrelationship of cropping practices and subsurface drainage in farm management; and basic physical and chemical soil properties that can help characterize drainability of various soil types in the Province.

BACKGROUND

Since 1976, government agencies and private companies have become more actively involved in subsurface drainage research, extension, manufacturing and installation in Alberta.

¹Mr Broadfoot is a Senior Consultant with Stanley Associates Engineering Ltd. Calgary, and is President of the Alberta Land Drainage Association.

Also, various government departments have initiated applied research programs to develop standards and guidelines for investigation, design and installation of subsurface drainage systems. Accompanying this proliferation of activities, the need for coordination and cooperation among those involved has become apparent. Alberta Agriculture therefore commissioned this study in Spring of 1982 to summarize and evaluate existing information regarding subsurface drainage research and practices in Alberta, and to identify where additional research and extension work is needed.

APPROACH

Data were gathered in the study through two main channels. (1) A literature search (computer-based and manual) was undertaken for relevant published and unpublished Alberta research on subsurface drainage. A total of eighty relevant publications or progress reports were reviewed; thirty-four of which were abstracted. (2) A series of interviews were conducted with twenty-seven key individuals involved with subsurface drainage in Alberta, including Suppliers, Contractors, Government, Irrigation Districts and Researchers. Following the collection of data, a review and evaluation was undertaken of the present state-of-the-art subsurface drainage practices and research in the Province. Conclusions were then drawn and recommendations developed.

CONCLUSIONS

Examination of the information gathered from the literature search and interviews suggests that the current body of knowledge and concerns about subsurface agricultural drainage in Alberta is centered on four main topics. The conclusions which were able to be drawn regarding each of these four topics are highlighted below.

(1) The Use and Applicability of Subsurface Drainage in Alberta

- (a) Subsurface drainage has been used to a much greater degree in the southern half of the Province, (Edmonton south) than in the northern half.
- (b) There is a diversity of viewpoints regarding the use of subsurface drainage as reclamation tool. There are those that place equal or greater emphasis on preventing salinization through measures such as cropping practices.

- (c) There is a need to determine and demonstrate to the farming community the value and cost-effectiveness of subsurface drainage as a reclamation tool, for both dryland and irrigated areas.
- (d) There is a diversity of experience and policies among the Irrigation Districts regarding the use of subsurface drainage, especially with regard to controlling canal seepage.
- (e) Within the Irrigation Districts it is important to insure that expansion of irrigation doesn't lead to increased salinity and waterlogging.
- (f) There is concern over the possible adverse impact that subsurface drainage effluent may have on the environment.

(1) Subsurface Drainage Practices in Alberta

- (a) There is a wide diversity of practices among those currently engaged in subsurface drainage.
- (b) With regard to the equipment, there appears to be equal emphasis placed upon the plow type and the bucket wheel or chain-drive type trenchers.
- (c) The laser plane for controlling grades during installation is widely accepted.
- (d) The state-of-the-art drain tile used in subsurface drainage in Alberta is perforated and non-perforated ribbed lightweight polyethylene tubing produced and supplied in coils by two Canadian manufacturers through local distributors.
- (e) With regard to investigation, design, and installation practices, there are two basic schools of thought among those involved. The first suggests that the investigation, design and installation should all be done by the contractor, using standard rules of thumb. The second school of thought is that the investigation and design should be undertaken by a competent professional (who may or may not be a contractor), treating each site as unique. Proponents of both schools of thought agree that more research is required to determine the applicability of existing out-of-province data to Alberta.
- (f) A stronger Alberta Land Drainage Association is advocated to help regulate the Industry.

(3) Government Participation in Subsurface Drainage in Alberta

- (a) The major areas of concern regarding government participation in subsurface drainage are related to coordination and communication between government agencies.
- (b) It may be beneficial to have drainage services to dryland and irrigated areas under one group instead of two, as they now exist.
- (c) Alberta Environment is being cautious in its treatment of applications for licenses, based on the present lack of knowledge regarding the potential adverse environmental impacts from subsurface drainage effluent.
- (d) There is a need to have a system or program that provides the opportunity for documenting and sharing advances in applied state-of-the-art. Several of the government agencies interviewed were not aware of what is coming out of ongoing or recent subsurface drainage research.
- (e) There is general agreement that the role of extension services is to provide assistance and education to the farming community. There are differing opinions however, regarding how technical the services offered by extension should be.

(4) Subsurface Drainage Research in Alberta

- (a) There is a significant amount of published research supporting the use of shallow subsurface drainage as an effective means of reducing and controlling soil salinity, especially in irrigated areas.
- (b) Published research indicates that subsurface drainage may be required to reclaim a saline soil even if the source of water, and salts, to the soil are controlled.
- (c) Published research indicates that the non-homogeneous nature of Alberta soils requires that individual, detailed investigations be undertaken for each drainage application and argues against the unqualified use of standardized drainage design guidelines (rules of thumb).
- (d) Topics receiving attention in current subsurface drainage research include: the depth and spacing requirements of subsurface drainage in Alberta; the hydrology of dryland seep areas and the relationship of hydraulic conductivity, texture, chemistry and porosity in different types of soil to subsurface drainage; tile drainage of waterlogged soils; slough-wetland drainage; hydrologic properties of soil in the Peace River area; the effect of deep plowing and subsurface drainage of solonchic soils.

- (e) Research projects are needed that will determine: the economic viability of on-farm subsurface drainage; the potential longterm adverse environmental impacts of subsurface drainage effluent, including mitigative measures; the applicability of existing out-of-province data to subsurface drainage practices in Alberta; the interrelationship of cropping practices and subsurface drainage in farm management; and basic physical and chemical soil properties that can help characterize drainability of various soil types in the Province.

RECOMMENDATIONS

- (1) Consideration should be given to forming a steering committee drawn from The Drainage Industry, Government and Research Groups involved with subsurface drainage in Alberta. The committee should: discuss, analyse and evaluate future research needs in subsurface drainage; prioritize needed subsurface drainage research; recommend funding measures, and; provide opportunities for communication between those involved in drainage research and practice.
- (2) The implementation of a direct subsidy program such as the one being contemplated by the Departments of Agriculture and Environment should prove helpful. The establishment of Drainage Districts based on non-political boundaries should also be considered in order to facilitate the subsidy program and provide common drains for outlets.
- (3) Action should be taken by the agencies within Alberta Agriculture and Alberta Environment to enhance coordination and communication.
- (4) The appropriate agencies of Alberta Agriculture should clarify the role extension services plays in subsurface drainage, especially with respect to the degree of technical expertise to be offered by District Agriculturists and Irrigation Specialists. The general level of extension efforts in subsurface drainage should be increased.
- (5) Irrigation Districts should consider undertaking measures to insure that irrigation expansion will not increase soil salinity or waterlogging.
- (6) More attention should be given by the Subsurface Drainage Industry to the Alberta Land Drainage Association.

MECHANICAL AND VEGETATIVE CONTROLS OF DRYLAND SALINE SEEPS

H.S.A. Vander Pluym¹

ABSTRACT

Dryland saline seepage is the major soil problem in the North Western Great Plains Region. Recommended controls are surface water drainage, alfalfa, recropping, subsurface water drainage, and salt tolerant crops. An investigation and advisory service was established in cooperation with the Dryland Salinity Control Association and was very effective in gaining interest, credibility and progress in controlling the problem. Through this service, main recharge areas are located and planted to alfalfa. The remainder of the recharge area is placed in a flex-crop program. Snow management practices such as alternate stubble heights and stubble barriers raise spring soil moisture by as much as 6 cm. Subsurface drainage in selected sites is capable of removing large quantities of ground water.

CONTROLS

Recommended dryland saline seep controls are; a) preventing the formation and deep percolation of "excess" water in the recharge area through surface water drainage, alfalfa and recropping; and b) lowering the water table or piezometric head in the discharge area by means of subsurface drainage and salt tolerant crops. Preventing the formation and deep percolation of "excess" water in the recharge area is the preferred measure because it controls the phenomenon at its point of origin and before it becomes a problem.

In order to determine which controls are most effective and at what location a detailed hydrogeological investigation is required of each saline seep and its upslope area. Ground water flow systems are complex and vary from site to site. To that end, Alberta Agriculture, Environment and P.F.R.A. established with the support of the Dryland Salinity Control Association, a dryland saline seep control investigation and advisory service. Special emphasis is placed on locating main recharge areas (see figure 1), which then can be planted to alfalfa. Each control merits further discussion:

¹ Soil Specialist, Plant Industry Division, Alberta Agriculture, Lethbridge

Surface Water Drainage:

Draining the intermittent natural or man-made ponds in the recharge area is an effective, important and often inexpensive control. Surface water drainage has several advantages over subsurface water drainage; a) it prevents deep percolation and saline seepage; b) the effluent is salt-free; c) the drained areas yield excellent crops immediately; d) outlets for upland ponds are more "available"; and e) the cost of construction is relatively small. An open trench or buried pipe is used. Shallow trenches can be constructed with farm equipment. Buried plastic corrugated pipe is rapidly gaining popularity because it permits the farmer to work across it.

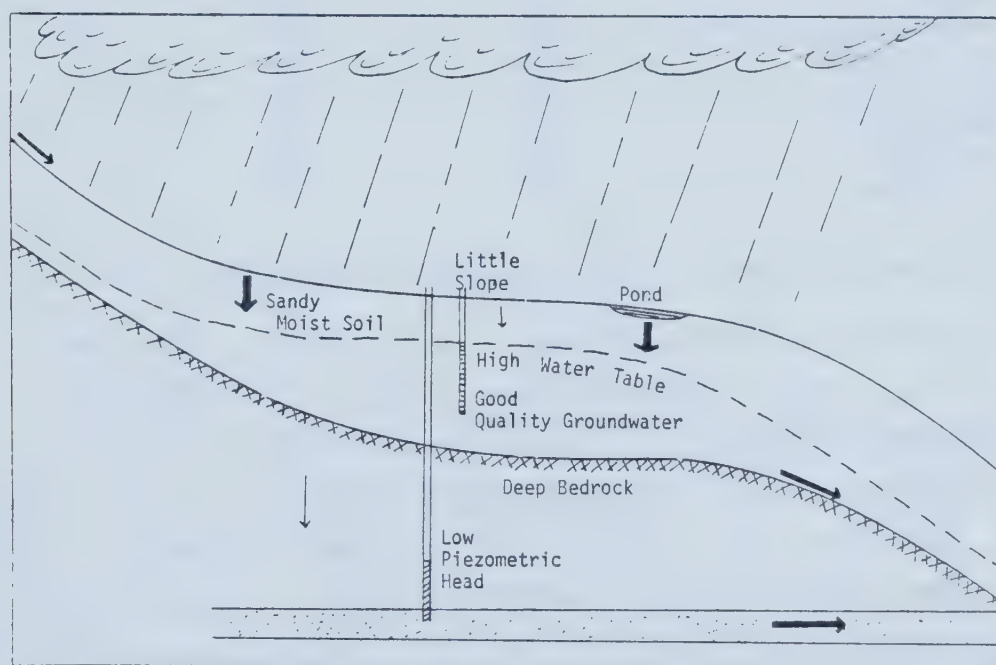


Figure 1: Main Recharge Area Characteristics.

Alfalfa:

The second dryland saline seep control is the use of high moisture use crops such as alfalfa, in the main recharge areas. Alfalfa, because of its deeper rooting system, its greater moisture use per unit of depth and its longer growing season uses more moisture than any other crop and is best capable of lowering the water table (see Table 1). Compared to cereal crops, alfalfa yields a lower net return and therefore the area to be planted to alfalfa is kept to a minimum.

Recropping:

The remainder of the recharge area should be recropped as often as possible. Black et al. (1981) indicated that longer rotations increase the precipitation

use efficiency. Flex-cropping, i.e. crop those years when spring soil moisture is over 10 cm, and a decent crop is assured is economically preferred. Unfortunately, it makes crop planning difficult and does not always optimize machinery capabilities.

CROPS	ROOTING DEPTH (cm)	CUMULATIVE WATER USE (cm)
Alfalfa (4 yr)		
(Beaver)	610	846
(Vernal)	550	666
(Rambler)	520	482
(Ladak)	490	673
(Kane)	370	505
Sainfoin	430	594
Russian Wildrye	300	475
Sweet Clover	270	403
Sunflower	200	206
Winter Wheat	170	195
Rapeseed	150	195
Spring Wheat	120	152

Table 1: Dryland Crop Rooting Depth and Water Use (Black, et al. 1981).

Special tillage and snow management practices are being researched to raise the level of spring soil moisture. Caprio (1980) noted that stubble fields accumulated twice as much snow as fallow fields, and the snow melt recharge efficiency (S.R.E.) stubble was 80% greater. He also noted that the S.R.E. in chinook areas was only 25% less than outside the chinook belt. Lindwall (1978) experimented with zero-tillage and obtained an additional 10-31 mm of spring plant available water and consequently, raised wheat yields 181-310 kg/ha in the Lethbridge area. Nicholaichuk (1982) reported that stubble barriers and alternate stubble heights raised spring soil moisture levels by 30-62 and 2-47 mm, respectively, in the Swift Current area. These promising practices improve the spectre of recropping. Unfortunately, the present poor economic situation of grain farming inhibits the rapid adoption of any type of recropping.

Subsurface Drainage:

Subsurface drainage of dryland saline seeps is an important control on selected sites. It is however, an expensive control and often generates saline effluent and therefore should be left as a last resort.

Before a subsurface drainage system is considered, a topographical survey and hydrogeological investigation of the proposed site should be carried out. The investigation should reveal the location of permeable

and impermeable strata, their texture, chemistry and hydraulic conductivity. In dryland, the systems are generally installed deeper than under irrigated or humid conditions. Research funded by Farming for the Future is underway to determine optimum depth and spacing of tiles in dryland. Preliminary results indicate that large drain flows of good quality water can be obtained (see Figure 2). The intent is to use the water of this project for irrigating.

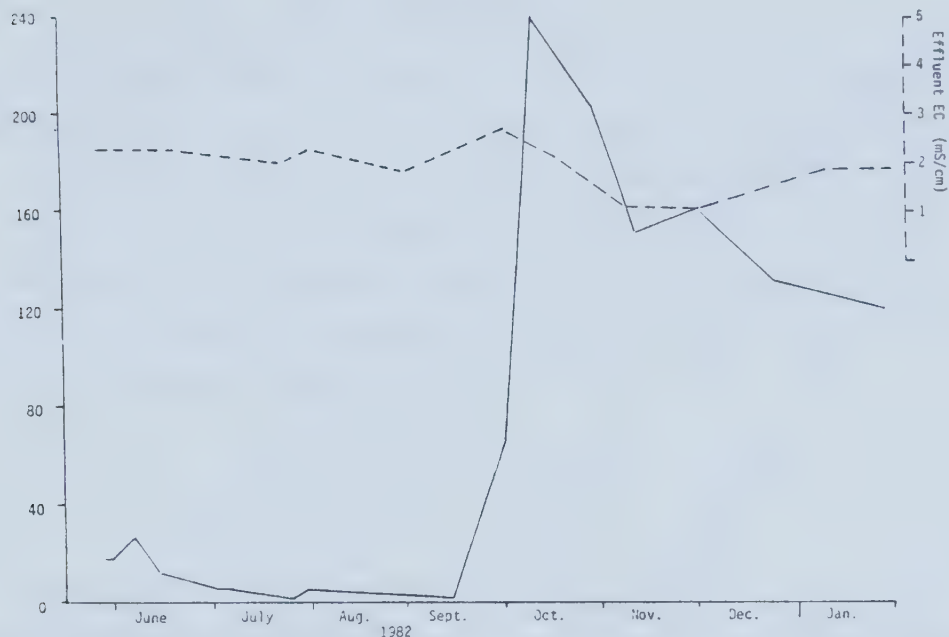


Figure 2: Effluent Quantity and Quality of the Akitt Subsurface Drainage Project 1982.

Other results indicate that the area of influence from a tile drain on the water table increases over the years. At the Thompson subsurface drainage site, the area of influence had increased after 4 years from half a meter to approximately 12 meters.

Salt Tolerant Crops:

The fifth control is planting the saline seep to salt tolerant crops. Grasses such as: Altai Wildrye, Intermediate Wheatgrass, etc., are generally recommended because of their high salt tolerance (see Figure 3). Salt tolerant annuals, especially six-row barley are beneficial in saline seeps that are subsurface drained. The lower evapotranspiration of cereals and the snow trapped in the stubble provide water for the leaching of salts.

CONCLUSIONS

Various dryland saline seep controls are known in theory. However, for several, data of their performance under our specific soil and climatic

conditions are lacking. The dryland saline seep control advisory and investigation service initiated recently in cooperation with the Dryland Salinity Control Association is most effective in gaining interest, credibility and progress. In the program, mainly vegetative controls are recommended.

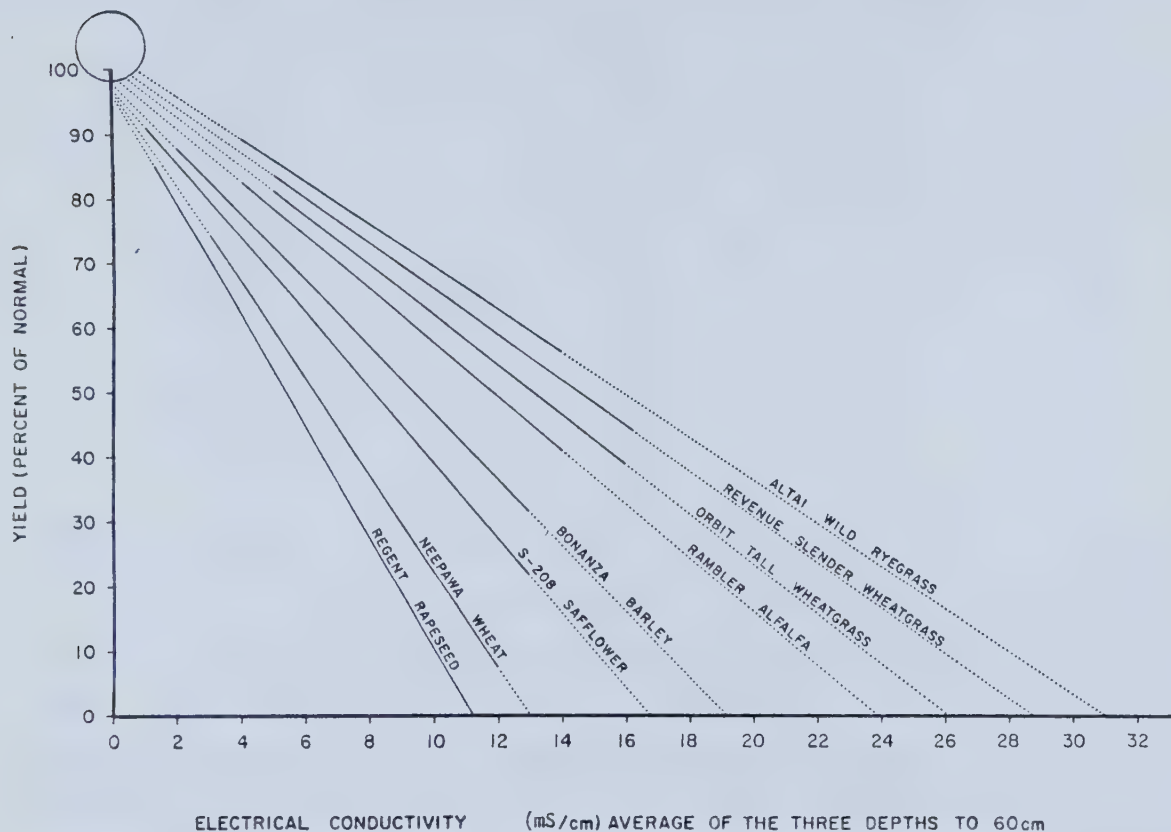


Figure 3: Salt Tolerance of Various Crops (Holm, 1982).

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RECLAMATION OF SODIC SPOIL: A PHYSICAL AND CHEMICAL APPROACH

S. Landsburg, M.Sc., P.Ag.¹

ABSTRACT

This paper deals with reclamation activities at two abandoned strip mines (Bow City and Forestburg South) in Alberta. At both mines sodic bedrock has been brought to the soil surface and activities involve amending the spoil to promote growth. Bottom Ash was tested as a physical amendment at Forestburg South. At Bow City calcium chloride was applied as a chemical amendment to improve the adverse physical and chemical properties associated with the spoil.

INTRODUCTION

This paper deals with reclamation activities at two abandoned strip mines in the Province of Alberta. Both areas were mined for coal before 1963. At that time there were only provisions for continuous back-filling and contouring of areas stripped of overburden to obtain coal. As a result, mined land was left as a series of spoil piles: no topsoil was conserved and the overburden removed was windrowed in the order of extraction.

The two strip mines of interest will be referred to hereafter as Bow City and Forestburg South. At both mines the bedrock formation overlying the coal is a fine-textured marine deposit of late Cretaceous age, whose prevailing constituent is bentonite. As a result of mining, the formations have been brought to the surface, creating problems in revegetation. The physical composition of the formations presents few problems. However, when the clay content and firm consistency are considered together with the chemical analyses, problems become apparent. The combination of a relatively high clay content and high concentrations of sodium results in materials which are very hard when dry, impermeable to water and roots, difficult to cultivate, subject to erosion, and subject to extreme shrink-swell pressures (Brocke 1976).

¹Reclamation Branch, Land Reclamation Division, Alberta Environment

BOW CITY

Bow City lies along the north bank of the Bow River, approximately 40 km southwest of Brooks, in the Eastern Alberta Plains. A road bisects the area into Bow City West (68 ha) and Bow City East (40 ha). All reclamation activities performed to date have been applied exclusively to Bow City East.

The spoil material at Bow City consists of friable till material with fragmented bedrock (Brocke 1976). Results of a soil sampling program performed in 1980 characterize the spoil as being saline-sodic (Table 1). Mean values of the top 30 cm of the material show it to be slightly alkaline (pH 7.6), saline (4.4 mmhos/cm) and sodic (SAR 21.2). Sodium is the dominant soluble cation (42.8 meq/l) and the texture is a clay loam. The saturation % is moderately high (78.5) reflecting the high salt concentrations and fine texture of the material.

Preliminary results of reclamation trials set up at Bow City by the Technical Development Branch of Alberta Environment showed topsoil applied to a depth of 10 cm and calcium chloride (CaCl_2) applied at 6600 kg/ha and incorporated to a depth of 10 cm, to produce the best yields under non-irrigated conditions (Graveland 1976). As a result, CaCl_2 was chosen as the chemical amendment to be used to replace the high concentrations of sodium and thus improve the physical and chemical properties of the spoil at Bow City.

In the fall of 1980, 6600 kg/ha of CaCl_2 was disced into the surface 15 cm of the spoil. In the spring of 1982, the areas was seeded and fertilized. A salt and drought tolerant grass mixture composed of 25% Fairway Crested Wheatgrass, 25% Prairieland Altai Wild Ryegrass, 25% Streambank Wheatgrass, and 25% Revenue Slender Wheatgrass was seeded at a rate of 25 kg/ha.

The Bow City site was monitored prior to application of the CaCl_2 in 1980 to the fall of 1982 (Table 1). Measurements were taken in 15 cm increments down to a maximum depth of 30 cm in 1980 and 60 cm in 1981 and 1982.

TABLE 1: CHARACTERISTICS OF BOW CITY SPOIL BEFORE AND AFTER CaCl_2 APPLICATION

ANALYSIS	DEPTH (cm)	YEAR		
		1980* No CaCl_2	1981** 6600 kg/ha CaCl_2	1982***
pH	0-15	7.5	7.3	7.4
	15-30	7.6	7.6	7.9
	30-45	-	7.6	7.6
	45-60	-	7.6	7.7
Saturation %	0-15	78.0	78.4	112.3
	15-30	79.0	82.1	115.3
	30-45	-	98.7	109.6
	45-60	-	103.5	104.3
E.C. (mmhos/cm)	0-15	4.2	5.1	6.4
	15-30	4.4	5.6	4.9
	30-45	-	5.2	5.7
	45-60	-	4.8	5.4
Ca^{+2} and Mg^{+2} (meq/l)	0-15	8.3	13.6	8.3
	15-30	8.9	11.2	3.4
	30-45	-	9.4	5.2
	45-60	-	8.9	5.7
Na^+ (meq/l)	0-15	41.8	42.5	65.4
	15-30	43.8	51.1	50.3
	30-45	-	48.8	59.7
	45-60	-	44.7	57.6
SAR	0-15	20.5	18.5	33.4
	15-30	21.9	26.1	40.0
	30-45	-	27.2	40.5
	45-60	-	27.1	36.6
Cl^- (meq/l)	0-15	-	21.1	20.2
	15-30	-	23.2	20.1
	30-45	-	11.7	23.1
	45-60	-	9.2	12.0

* Mean value of 9 samples

** Mean value of 7 samples

*** Mean value of 3 samples

In general, there were no changes in pH at all depths monitored. Saturation % values increased slightly in 1981. During 1982 these values increased a minimum of 33% within the top 30 cm of the spoil. Increases in saturation % then decreased with increased depth of the spoil.

Soluble calcium and magnesium values reached a maximum during 1981, reflecting the period when the majority of the CaCl_2 was in solution. Soluble sodium **values** increased each year at all depths monitored, as calcium from the CaCl_2 replaced sodium from exchange sites.

In general, SAR values increased each year at each depth monitored. Chloride concentrations increased from trace amounts at all depths to an average of 20 ppm within the top 45 cm of the spoil.

The results discussed above show that the addition of CaCl_2 to sodic spoil has lead to the replacement of exchangeable sodium by calcium. The replaced sodium is then being leached downwards as sodium chloride.

A major effect of the CaCl_2 application which was not measured was a visible improvement in soil tilth. The spoil became more friable, less able to crust or seal and more workable. As a result there was a large increase in seed germination.

FORESTBURG SOUTH

The Forestburg South site is situated on the south side of the Battle River approximately 180 km southeast of Edmonton, in East Central Alberta. This site consists of three separate areas totalling 220 ha. Due to the availability of bottom ash from a coal-fired thermal generating station and preliminary results of work done by Shaneman (1978), it was decided to test bottom ash as a physical amendment to sodic spoil. It was felt that application of bottom ash to sodic spoil would improve water, air, and root penetration, and promote leaching, therefore, resulting in the removal of excess sodium.

Bottom ash plots were constructed in October 1981. Objectives of the plots were: to test bottom ash as an amendment to sodic spoil; to

determine the optimum rate of application of bottom ash; to physically and chemically characterize bottom ash; and to determine the best method of incorporating bottom ash into spoil.

The plots were set up as a simple factorial experiment (Figure 1). Each plot was 10 m by 20 m and was separated from neighboring plots by a 2 m buffer. There were three replicates consisting of 12 plots each. Each replicate was separated by a 10 m buffer zone.

The three depths of bottom ash tested were 10, 20, and 30 cm. Ash was applied to the spoil surface using a D-8 crawler tractor and incorporated using a disc, chisel plow, and Kellough Subsoiler. A fourth test included leaving the ash as a blanket on top of the spoil.

The plot areas were sampled before and after bottom ash application in order to chemically and physically characterize the spoil and bottom ash (Table 2).

The spoil material consisted chiefly of bedrock material which was moderately alkaline (pH 8.0), moderately saline (E.C. 3.3 mmhos/cm), and sodic (SAR 28.1). Sodium was the dominant soluble cation (39.4 meq/l) and sulfate was the dominant soluble anion (42.0 meq/l). The spoil had an extremely high saturation % (154%), and had a silty clay loam texture.

The bottom ash was slightly alkaline (pH 7.9), slightly saline (E.C. 2.0 mmhos/cm), and was moderately sodic (SAR 13). Sodium was the dominant soluble cation (17.5 meq/l) and sulfate was the dominant soluble anion (17.2 meq/l). The ash had a moderately high saturation % (87%), and had a sandy loam texture. Predominant trace elements consisted of B, Ni, and Fe, however all were non-toxic levels.

In the summer of 1982, each plot was hand-seeded and fertilized. A mixture of 25% Sodar Streambank Wheatgrass, 25% Tall Wheatgrass, 25% Fairway Crested Wheatgrass, and 25% Rambler Alfalfa was seeded at a rate of 24 kg/ha.

Yield measurements were taken in the fall of 1982 (Table 3). Preliminary results showed an application of 30 cm of bottom ash incorporated using a chisel plow to yield highest results. Twenty cm of ash incor-

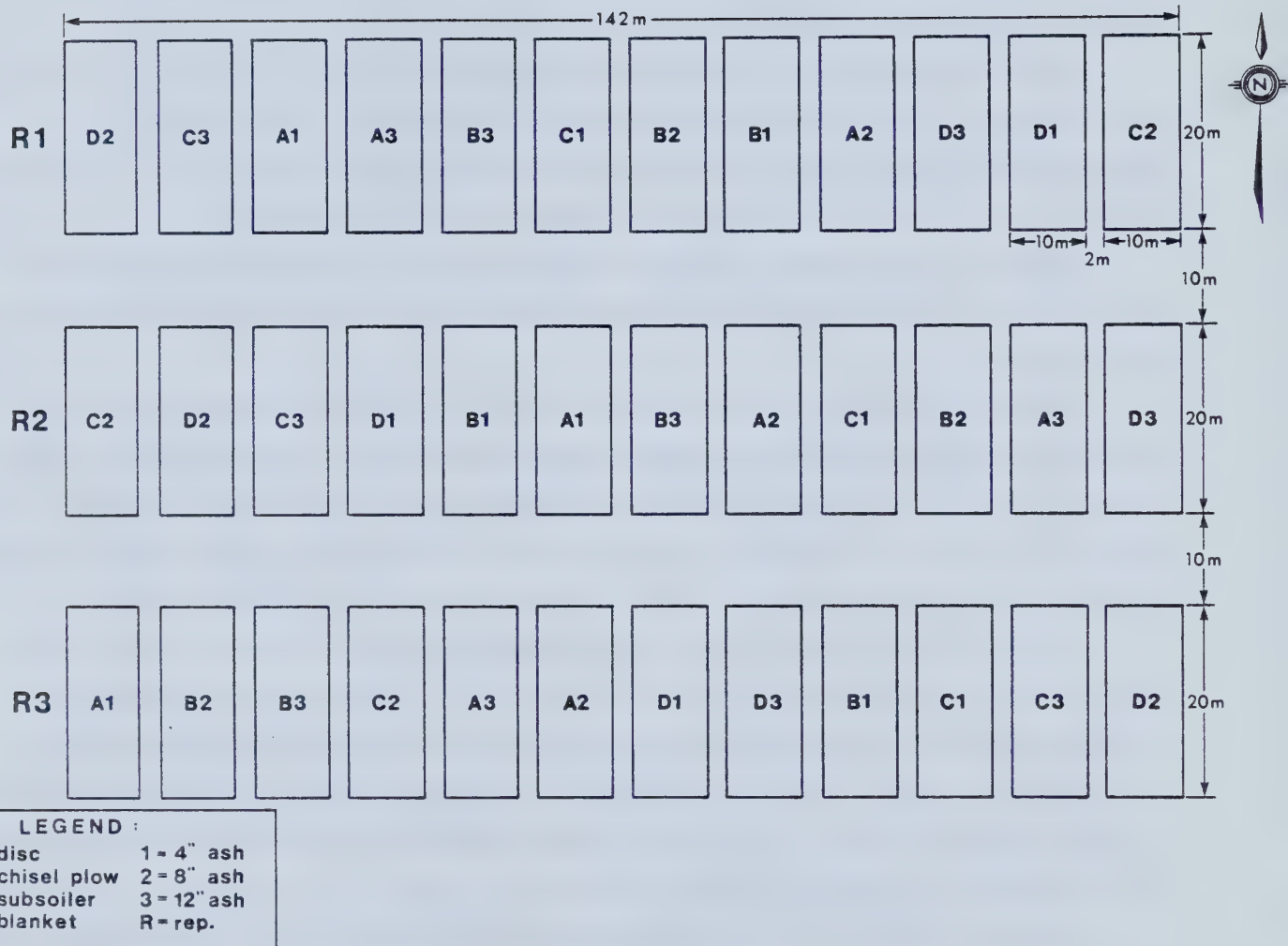


FIGURE 1: BOTTOM ASH PLOTS AT FORESTBURG SOUTH

TABLE 2: SOME PHYSICAL AND CHEMICAL PROPERTIES OF BOTTOM ASH AND SPOIL FROM THE BOTTOM ASH PLOTS

<u>ANALYSIS</u>		<u>SPOIL (0-15 cm)*</u>	<u>ASH (0-15 cm)**</u>
pH		8.0	7.9
E.C. (mmhos/cm)		3.3	2.0
Soluble Cations (meq/l)	Ca ⁺² and Mg ⁺²	4.9	3.8
	Na ⁺	39.4	17.5
	K ⁺	0.9	0.6
SAR		28.1	13.0
Soluble Anions (meq/l)	SO ₄ ⁻²	42.0	17.2
	HCO ₃ ⁻	7.0	4.9
Saturation %		154.0	87.0
Texture		SiCl	SL
Trace Elements	B	--	2.9
	Ni	--	41.6
	Fe	--	8.9

* Mean values of 36 samples taken before bottom ash was applied.

** Mean values of 36 samples taken once the ash had been spread over the plots.

TABLE 3: YIELD MEASUREMENTS AT BOTTOM ASH PLOTS 1982

<u>TREATMENT</u>		<u>YIELD*</u> (gm/m ²)
A1	Disc 10 cm ash	25.2
A2	Disc 20 cm ash	35.8
A3	Disc 30 cm ash	23.6
B1	Chisel Plow 10 cm ash	28.0
B2	Chisel Plow 20 cm ash	65.8 ²
B3	Chisel Plow 30 cm ash	70.1 ¹
C1	Subsoiler 10 cm ash	24.0
C2	Subsoiler 20 cm ash	40.6 ³
C3	Subsoiler 30 cm ash	19.4
D1	Blanket 10 cm ash	11.3 ¹²
D2	Blanket 20 cm ash	17.1 ¹¹
D3	Blanket 30 cm ash	31.8

* Mean value of 9 samples

1, 2, 3, 11, 12 Rating of yields from highest to lowest.

porated using the chisel plow was the second most effective treatment followed by 20 cm of ash incorporated with the subsoiler. Poorest results occurred when 10 cm and 20 cm of ash were applied as blankets over the spoil.

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EVALUATION OF PIPELINE RECLAMATION

PRACTICES ON AGRICULTURAL

LANDS IN ALBERTA

By

W. John Hastie, H.E. Martens, D.L. Johnson and C.G. Heath¹

ABSTRACT

The purpose of the study was to review pipeline reclamation practices used in Alberta, define the effects of pipeline construction and reclamation practices and recommend optimal reclamation techniques which will minimize adverse effects.

Information was gathered and reviewed to gain a perspective of common construction and reclamation methods and equipment used in Alberta and to examine documented effects of pipelines on agricultural land in Alberta and elsewhere.

Following the review a field survey of 154 sites on existing pipeline routes in Alberta was conducted. The purpose of the field survey was to document the general success or failure of pipeline reclamation and provide an indication of causes of success or failure.

Topsoil was salvaged at most (75%) annually cropped and irrigated sites, at about half of the tame pasture sites and at very few (9.5%) of the native pasture sites examined during the field survey.

Only 13% of all the sites examined had topsoil replaced over the trench unmixed with subsoil. A similar proportion of the total sites had unmixed topsoil over the stockpile areas while half of the 154 sites had unmixed topsoil over the working areas.

Even though topsoil has been mixed with subsoil at many sites this does not always result in poorer plant growth. This is particularly evident in annually cultivated Black Chernozemic Soils and on trench areas in Brown Solonetzic Soils.

On all other soil types examined, the majority of sites where topsoil was mixed, buried or absent also had crops that were at least 10% thinner, shorter or weedier than adjacent undisturbed areas.

¹ Members of Environmental Division, Hardy Associates (1978) Ltd.

INTRODUCTION

There are thousands of kilometers of underground pipelines in Alberta which when plotted on a map of the province resemble a detailed road map. They vary in size from 50 mm to 1420 mm and commonly transport oil, gas or water. There is concern that the capability of agricultural land to produce annual crops, forage and native pasture may be significantly reduced by some types of pipeline construction activities. Consequently a study was initiated by the Reclamation Research Technical Advisory Committee to evaluate pipeline reclamation practices on agricultural land in Alberta. The study was completed by Hardy Associates (1978) Ltd. and the final report is in press (Hardy Associates, 1983).

The purpose of the study was to review pipeline reclamation practices used in Alberta, define the effects of pipeline construction and reclamation practices and recommend optimal reclamation techniques which will minimize adverse effects.

The approach taken to the study, and key results regarding topsoil salvage, condition of replaced topsoil and the response of annual crops, forage and native pasture will be reviewed in this paper.

APPROACH

Information was gathered from available literature, pipeline owners and pipeline construction companies to gain a perspective of common construction and reclamation methods and equipment used in Alberta. The review also examined documented effects of pipelines on agricultural land in Alberta and elsewhere.

Following the review a field survey of 154 sites on existing pipeline routes in Alberta was conducted. The purpose of the field survey was to document the general success or failure of pipeline reclamation and provide an indication of causes of success or failure.

Sites were selected for field examination in each soil zone, on annually cropped, improved forage and native pasture lands, on solonchic and non solonchic soils and on coarse and fine textured soils. The sites were also selected so that a variety of pipeline sizes (76 to 1220 mm) and ages (1 to 69 years old) were included. (Table 1, Figure 1).

Field examinations were conducted in July and August 1981 when the crops and forage were sufficiently mature to evaluate. At each site soil profile characteristics and vegetation cover and height, were noted on the trench, working and stockpile areas as well as on an adjacent location undisturbed by pipeline construction. (Figure 2) Crop head length and weedy species type and abundance were also noted at many sites.

The results of the field survey were evaluated as differences or changes over the trench, working and stockpile areas relative to the adjacent undisturbed areas (controls).

Because of the large number of variables included in the sites examined during the study it was not within the scope of the study to quantify the effects of each on soil capability or productivity. However the following general trends have been identified from the data.

RESULTS AND DISCUSSION

Topsoil Salvage

A survey of pipeline companies indicates that virtually all pipeline construction during the past 10 to 15 years has included plans for topsoil salvage in agricultural areas. In some cases, these plans have been limited to locations where landowners have requested topsoil salvage. In most cases topsoil is salvaged only over the trench area although, on cultivated areas in particular, topsoil has also been salvaged from the stockpile area. Infrequently, and only at the request of the landowner, topsoil will be salvaged over the entire right-of-way. In a few cases the landowner has requested that topsoil not be salvaged.

The most commonly used equipment for moving topsoil from the trench to storage area is a bulldozer or rubber tired grader. Other types of equipment include the ditcher/conveyor, backhoe and power dozer.

Topsoil was salvaged from approximately half of all sites examined in the field survey. At 83% of the sites where topsoil was salvaged it was salvaged over the trench only. At the remainder topsoil was salvaged over the trench and stockpile areas (5%) or over the entire right-of-way (12%). Topsoil was salvaged at most (75%) annually cropped and irrigated sites, at about half of the tame pasture sites and at very few (9.5%) of the native pasture sites (Figure 3).

Topsoil Replacement

Backfilling of subsoil and topsoil is usually done with a bulldozer and blade or with a "Mormon Board" attached to a sideboom or crane. In most cases the spoil material is backfilled and tamped with a bulldozer or rubber-tired vehicle and then the topsoil is spread over the area that had previously been stripped. In some areas, however, where separate topsoil replacement has not been specified, both the topsoil and subsoil piles are backfilled simultaneously.

A high proportion of sites examined during the field survey had mixed topsoil and parent material or no topsoil on the surface of the trench and stockpile areas (Figure 4). The working areas often had this same mixing or absence of topsoil although not as frequently as over the trench and stockpile areas.

Only 20 to the 154 sites (13 percent) examined had topsoil replaced over the trench unmixed with subsoil. A similar proportion of the total sites had unmixed topsoil over the stockpile areas while half of the 154 sites had unmixed topsoil over the working areas.

Similar trends in the proportions of sites with unmixed and mixed topsoil were found for annually cultivated sites and tame pasture sites. On native pasture sites where the frequency of topsoil salvage was low, a higher proportion of sites had buried topsoil over the stockpile and work areas and no topsoil over the trench. Sites which had topsoil mixed with B horizon only were confined to annually cultivated and tame pasture sites in the Gray and Black soil zones.

Vegetation Responses

Annual crops, tame grasses and legumes and native pasture species on the right-of-ways were considered to be poorer than adjacent control areas if their estimated cover and/or height was more than 10% lower. They were also considered to be poorer if weedy species were noticeably more abundant than on adjacent areas. Vegetation was considered to be unchanged if the cover and height on the right-of-way was within 10% of adjacent areas and the abundance of weedy species was unchanged.

The overall trend is shown in Figure 5. Over half of all the sites examined in the study had poorer vegetation on the trench, stockpile and work areas than on adjacent control areas. Conversely about 13% of the sites had improved vegetation and 30% were unchanged.

The trend on annually cropped and tame pasture sites is similar to the overall trend. However a higher proportion of native pasture sites had poorer vegetation.

Vegetation Responses on Solonetzic and Non Solonetzic soils:

Poor vegetation was found on a high proportion of all sites with Solonetzic soils (Figure 6). This is most pronounced for native pasture where nearly all sites were weedier and had less total cover.

On annually cropped and tame pasture sites with Solonetzic soils there is a noticeably higher frequency of poorer vegetation over the stockpile areas than over the trenches. In fact over the trenches on annually cultivated sites two thirds of the sites had crop growth that was improved or unchanged from adjacent controls. The reverse is true for stockpile areas in annually cultivated areas where 62% of the sites had poorer crop growth. The poorer vegetation over the stockpile and working areas appears to be the result of topsoil which has been mixed with or buried by saline parent material. This chemical effect on vegetation also appears to be balanced or masked by the beneficial effect of loosening and improving the subsoil structure in the trench resulting in noticeably fewer trench areas with poorer vegetation.

The trends on non-solonetzic soils (Figure 7) are generally not as severe. Poorer vegetation occurred at about half of the sites in this category. This trend prevails for both annually cultivated and tame pasture sites while a higher frequency of poorer vegetation was found on trench and stockpile areas in native pasture. The difference between the response on trenches and stockpile areas in solonetzic soil is not evident on Chernozems or Luvisols.

Differences in Vegetation Response by Soil Zone:

The frequency of poorer vegetation occurring on trench, stockpile and working areas is lowest on sites in bush pasture in the Gray soil zone, and on annually cultivated and tame pasture sites with Black Chernozemic soils (Figure 8). In contrast well over half of the annually cultivated and tame pasture sites in the Gray and Brown and Dark Brown Soil Zones had poorer vegetation. Few of the trenches on annually cultivated solonetzic sites in the Brown and Dark Brown soil zones had poorer vegetation (Figure 9). The previously mentioned contrast in vegetation response between the trenches and stockpile areas in solonetzic soils is evident in the Brown and Dark Brown and Black soil zones on both annually cultivated and tame pasture sites.

Weediness:

The abundance of weeds was found to be greater on the right-of-way than on adjacent areas at 56% of all tame pasture sites and 83% of all native pasture sites. In contrast only 20% of all cultivated sites had increased weediness. This recurring problem in both tame and native pasture is likely the result of the competitive advantage weedy species have during revegetation, particularly under poorer soil conditions where topsoil has been mixed or buried. From the results it appears that even a thin 5 to 10 cm layer of C horizon material on the surface will provide a competitive edge to weedy species during revegetation and that these species persist over time unless controlled by management practices. Where improved forage has been managed and cut annually weeds are less frequent. Under pasture weedy species have persisted on the rights-of-way over pipelines as old as 24 years.

On a few native pasture sites revegetation with grass species different from the adjacent field can result in pasture management difficulties. This was evident where timothy was dominant over rights-of-way through native fescue pastures.

CONCLUSIONS

1. Topsoil is most commonly salvaged over the trench area of rights-of-way in annually cropped land. Topsoil salvage has been infrequent on native pasture land.
2. Only 13% of the sites examined had unmixed topsoil replaced over the trench. A similar proportion had unmixed topsoil over the stockpile area while half of the sites had unmixed topsoil over the working areas.
3. The following factors alone or in combination may have resulted in the high proportion of sites with mixed, buried or no topsoil over at least part of the right-of-way:
 - the common method of stockpiling topsoil adjacent to and often abutting the spoil pile;
 - the commonly used "Mormon Board" or bulldozer for backfilling;
 - the presence and disposal by levelling over the right-of-way of excess spoil as a result of bulking or displacement by the larger pipes;
 - topsoil salvage deeper than the depth of topsoil present;
 - landowner requests for no topsoil salvage; and
 - additional traffic and introduction of additional soil material when rebackfilling and levelling is needed after trench settlement, particularly on irrigated land.
4. It is evident from the results that even though topsoil has been mixed with subsoil at many sites this does not always result in poorer plant growth. This is particularly evident in annually cultivated Black Chernozemic Soils and on trench areas in Brown Solonchaks.

5. On all other soil types examined, the majority of sites where topsoil was mixed, buried or absent also had crops that were at least 10% thinner, shorter or weedier than adjacent undisturbed areas.
6. On improved and native forage sites poorer crops appear to be in large part the result of increased weediness which is enhanced where topsoil is mixed, lost or buried. A combination of improved soil salvage and replacement, cattle control during revegetation and use of weed control practices would improve this result

ACKNOWLEDGEMENTS

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Table 1. Summary of sites examined.

All Soil Zones	Luvisolic/ Chernozemic	Solonetzic	Total
Annual Crops			
- Total	50	21	71
- Dryland	(46)	(21)	(67)
- Irrigated	(4)	(0)	(4)
Improved Pasture			
- Total	30	11	41
- Dryland	(27)	(11)	(45)
- Irrigated	(3)	(0)	(3)
Native pasture	27	15	42
Total	107	47	154
Pipeline Age Range:	1 to 69 years old		
Pipeline Size Range:	76.2 to 1219 mm		



SOIL ZONES OF ALBERTA

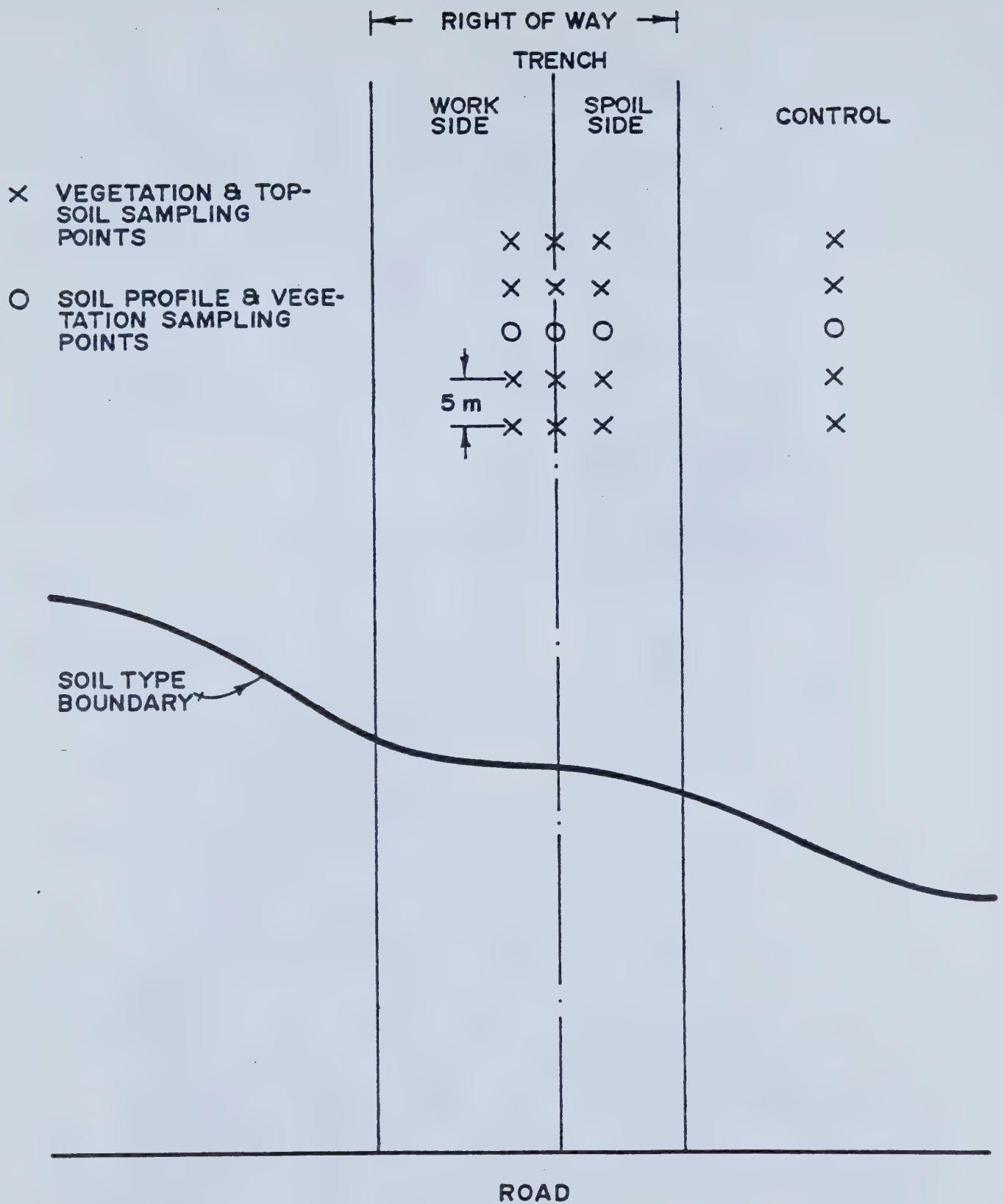


FIG. 2 SCHEMATIC DIAGRAM OF TYPICAL SITE LOCATION AND SAMPLING POINTS

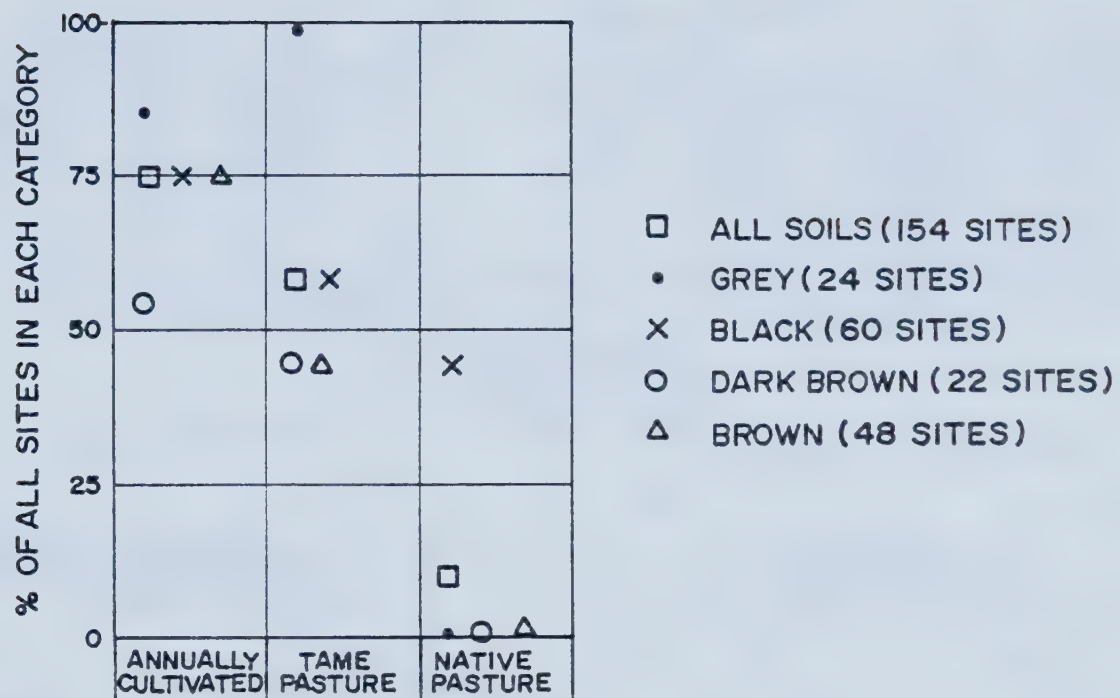


FIG. 3 FREQUENCY OF TOPSOIL SALVAGE ON PIPELINE RIGHT
OF WAY SITES INVESTIGATED IN ALBERTA

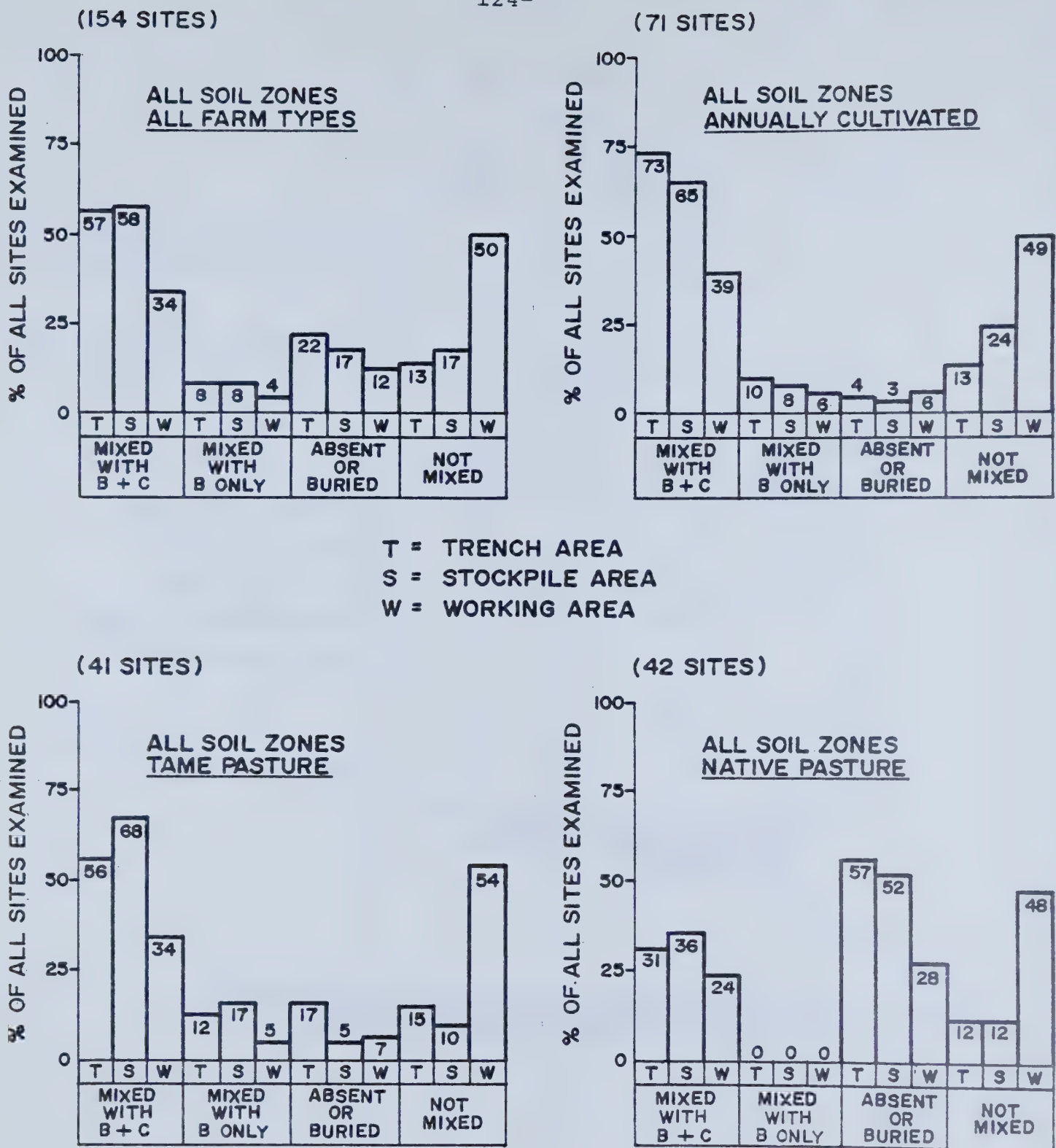


FIG. 4 CONDITION OF REPLACED TOPSOIL ON PIPELINE RIGHT OF WAY
SITES INVESTIGATED IN ALBERTA

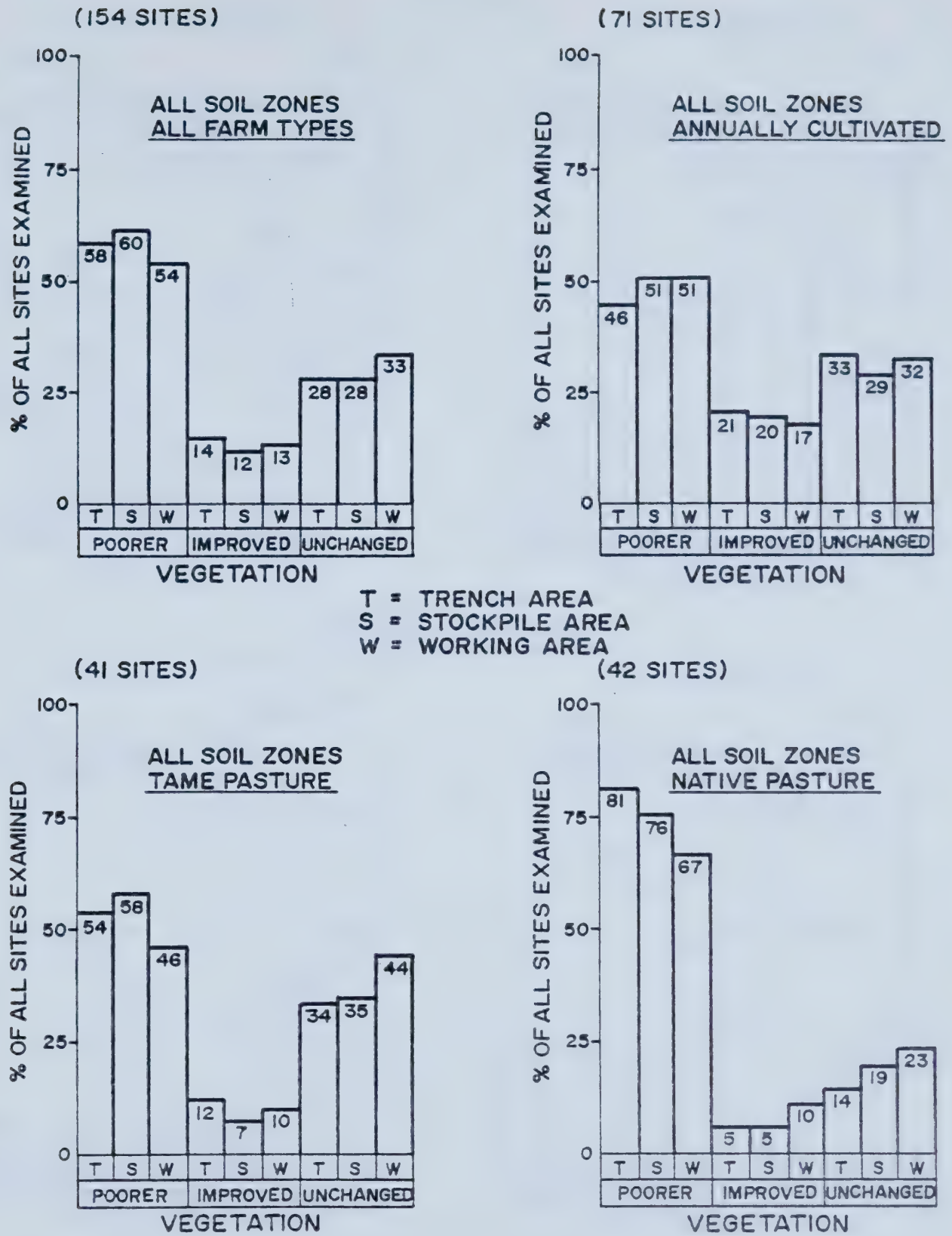


FIG. 5 VEGETATION CHANGES ON RIGHT OF WAY SITES INVESTIGATED IN ALBERTA

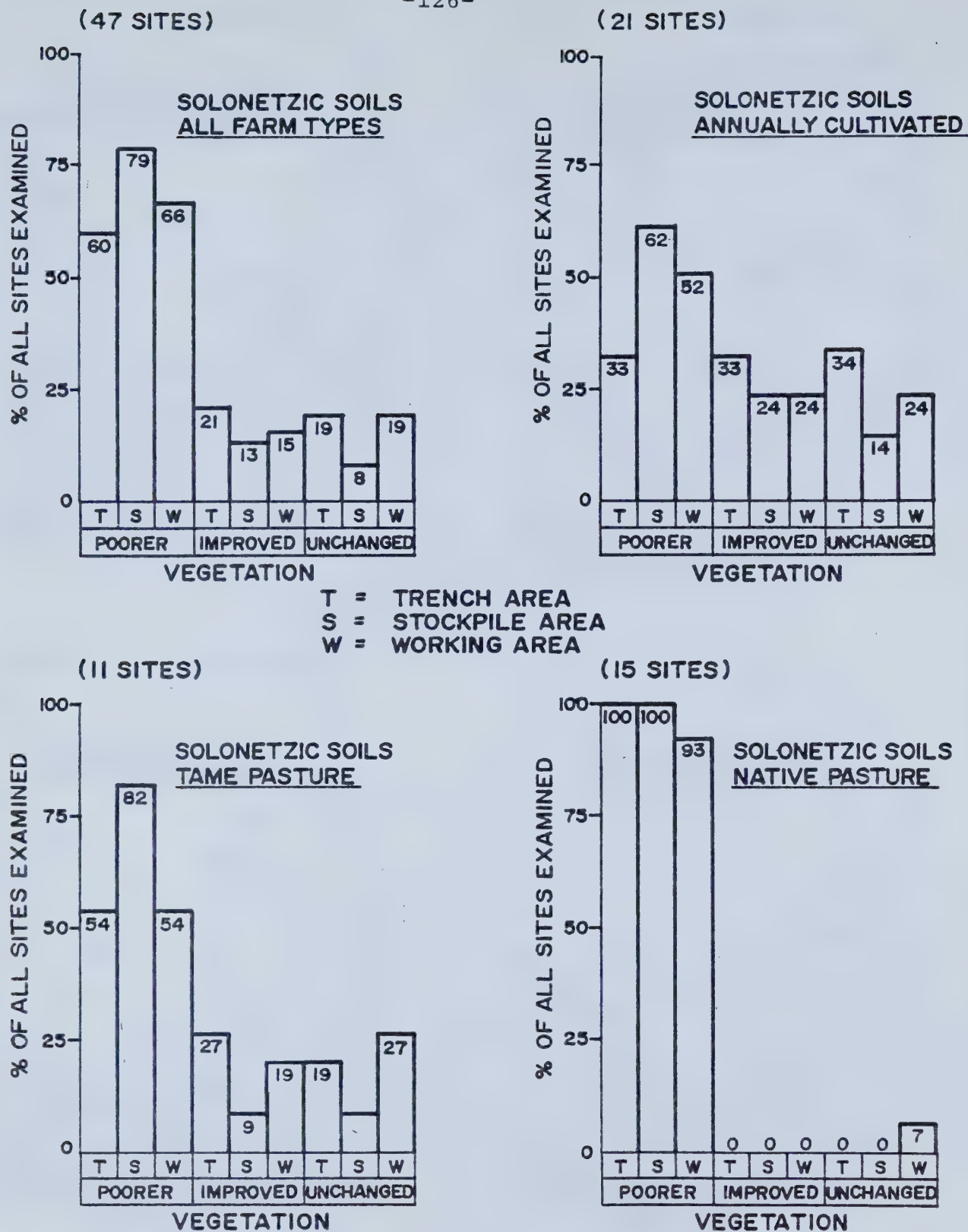


FIG. 6 VEGETATION CHANGES ON PIPELINE RIGHT OF WAY SITES
INVESTIGATED ON SOLONCHETZIC SOILS IN ALBERTA

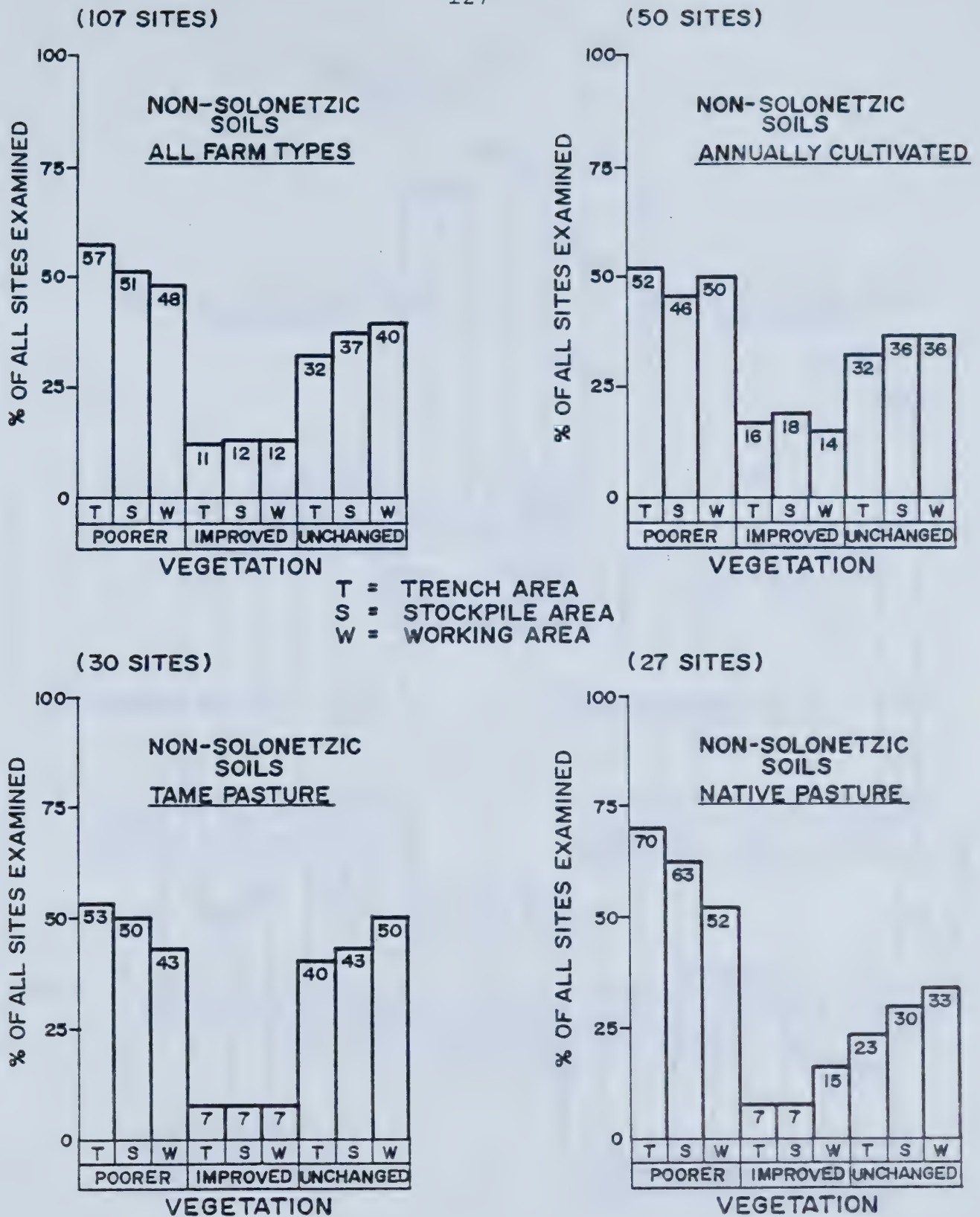
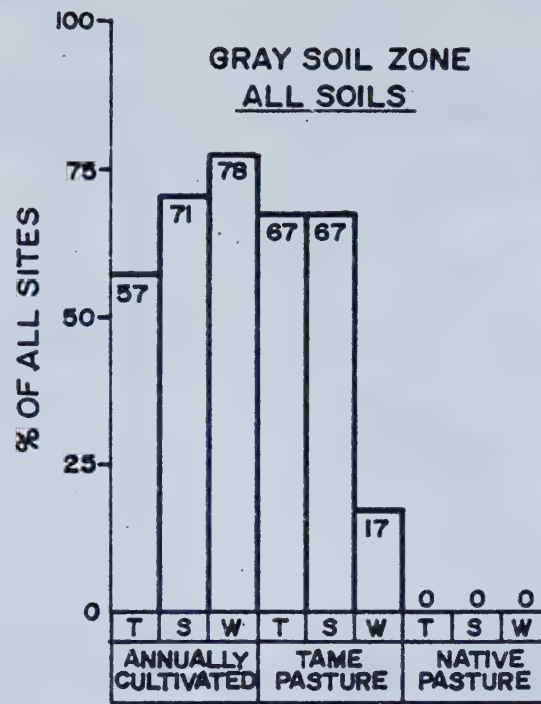


FIG. 7 VEGETATION CHANGES ON PIPELINE RIGHT OF WAY SITES
INVESTIGATED ON NON-SOLONETZIC SOILS IN ALBERTA



T = TRENCH AREA
S = STOCKPILE AREA
W = WORKING AREA

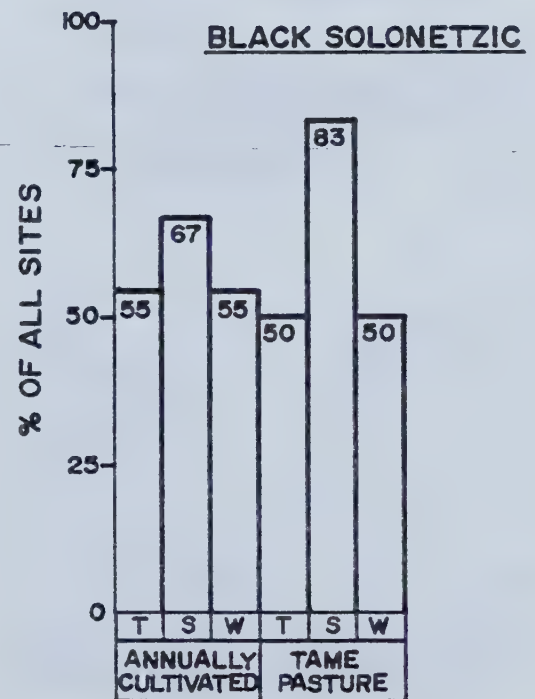
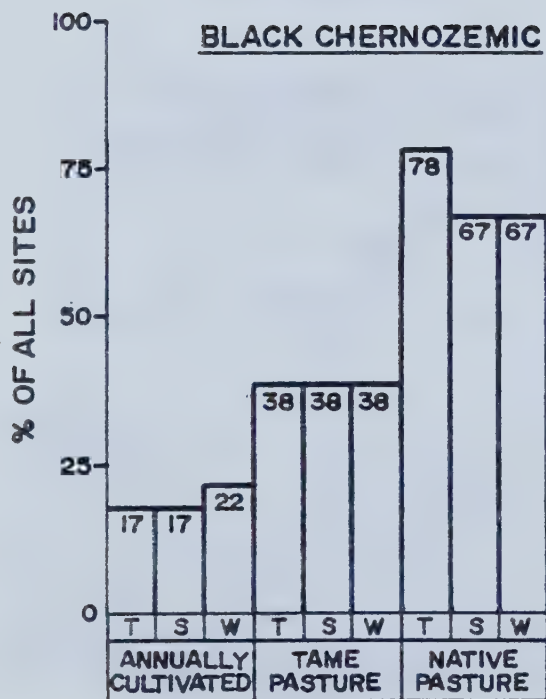


FIG. 8 RELATIVE FREQUENCY OF POORER ANNUAL CROPS, TAME PASTURE AND NATIVE PASTURE ON PIPELINE RIGHT OF WAY SITES INVESTIGATED IN THE BLACK AND GRAY SOIL ZONES

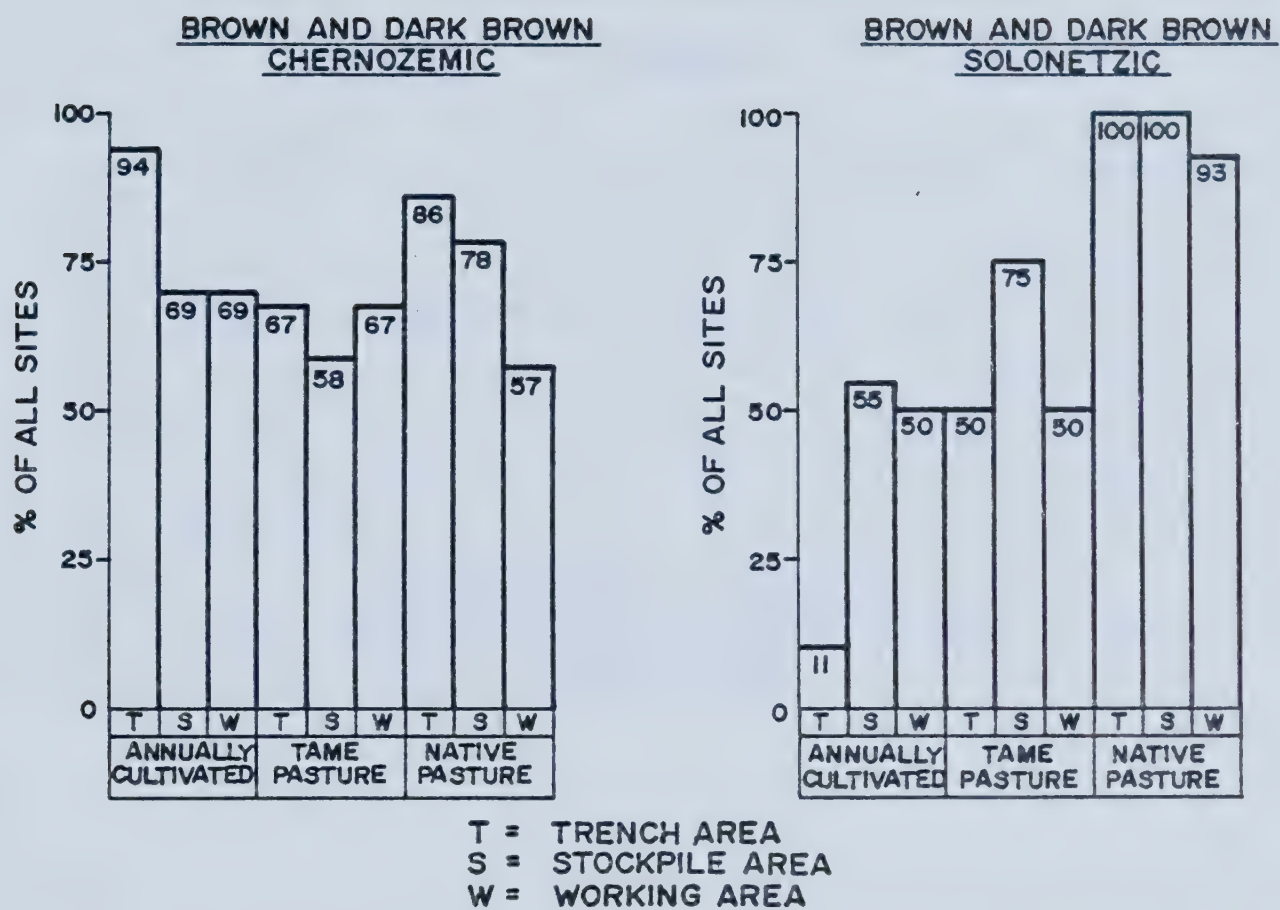


FIG. 9 RELATIVE FREQUENCY OF POORER ANNUAL CROPS, TAME PASTURE AND NATIVE PASTURE ON PIPELINE RIGHT OF WAY SITES INVESTIGATED IN THE BROWN AND DARK BROWN SOIL ZONES

EVALUATION OF THE WINTER TOPSOIL STRIPPING MACHINE
ON NOVA PIPELINES

by

D. G. Paton and A. W. Fedkenheuer

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NOVA, AN ALBERTA CORPORATION
Environmental Affairs Department
Alberta Gas Transmission Division
P.O. Box 2535, Postal Station M, Calgary, Alberta

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MACHINE ON NOVA PIPELINES

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D. G. Paton and A. W. Fedkenheuer¹

ABSTRACT

In the winter of 1981/1982, NOVA, AN ALBERTA CORPORATION used its topsoil stripping machine in the construction of pipelines at Gleichen, Mikwan and Hythe. A soil sampling program was initiated in May 1982 to assess soil quality, through soil chemical and physical parameters, at on and off right-of-way locations following final cleanup on sites where the topsoil stripping machine was used. Bulk density, texture, pH, EC and calcium carbonate values were determined for all samples, while organic matter, modulus of rupture and available nutrients were determined on surface samples only. The results revealed that there was no effect on bulk density or soil compaction at any depth or location. However, pH, EC, clay, calcium carbonate and organic matter contents, and modulus of rupture values were significantly different at the trench location than off right-of-way. These soil characteristics appeared to be slightly lower at the 0-15 cm depth on the spoil side also. Based on these first-year results, it would appear that this method of pipeline construction may be best suited to soils most susceptible to compaction with high clay and/or those with low organic matter contents. This study is being continued to examine longer term results and their effect on soil capability.

¹Soil Scientist and Supervisor, Research and Development, respectively.
Environmental Affairs, NOVA, AN ALBERTA CORPORATION, P.O. Box 2535, Postal
Station M, Calgary, Alberta.

INTRODUCTION

In December 1980 NOVA, AN ALBERTA CORPORATION first attempted to conserve topsoil in the winter on cultivated land in the Lac La Biche area. There was a desire both on the part of NOVA and regulatory agencies, principally Alberta Environment, to conserve topsoil over the ditchline. However, there was no available machine with the capability to remove frozen topsoil in a satisfactory manner. NOVA experimented with a variety of equipment and techniques, including asphalt planers, ripping over ditchline prior to using a step-blade, and attempting to remove the topsoil layer using a Barber-Greene ditching wheel. None of the methods used were satisfactory, and, in 1981 NOVA embarked on a research program to develop a machine suitable for the task of stripping frozen topsoil.

A machine with some capability was found in Texas. It was a Roc-Saw Trencher, and Roc-Saw International Ltd. worked with NOVA to design a cutter bar assembly suitable for removing frozen topsoil. Extensive modifications to an existing machine were made, and the topsoil stripping machine was ready in December 1981 for the winter construction season. A more complete history of the development and description of the topsoil stripping machine has been presented elsewhere (Morck, 1982).

The topsoil stripping machine was used on three pipeline construction projects in the winter of 1981/1982 (Figure 1). The Gleichen Lateral is located about 100 km east of Calgary, the Mikwan Lateral is approximately 60 km east of Red Deer, and the Hythe Lateral is just to the northwest of Beaverlodge, Alberta. In the spring of 1982 a research program was initiated to assess soil quality on and off the rights-of-way of these three pipelines in an attempt to evaluate the performance of the topsoil stripping machine.

MATERIALS AND METHODS

The three pipeline laterals cover a variety of soil types encountered across the province. The Gleichen Lateral is in Orthic and Solodic Brown and Dark Brown Chernozems. Mikwan Lateral soils are mainly Orthic Dark Grey, Orthic Black and Eluviated Black Chernozems. The Hythe Lateral soils are Orthic Grey and Dark Grey Luvisols.

The topsoil stripping machine was monitored closely during its operation, and the depth of topsoil stripping was based on a distinct colour change between the A and B horizons. The topsoil was deposited on the working side of the right-of-way approximately 2 m from centreline of the ditch. In subsequent operations, the pipe was strung out and welded on or next to the topsoil pile. The ditching machine excavated the trench and all subsoil was piled on the spoil side of the right-of-way to prevent mixing with the topsoil. The pipe was lowered in following welding and the subsoil



FIGURE 1: LOCATION OF GLEICHEN, MIKWAN AND HYTHE LATERALS

was replaced using a dozer. The last operation during the winter season was machine cleanup which smoothed out the right-of-way, but left the topsoil pile intact. Final cleanup occurred in late May and early June, at which time the backfilled trench was compacted and bladed smooth prior to topsoil replacement. A balloon-tired grader was used to replace the topsoil on the Mikwan and Gleichen Laterals; a regular grader was used on Hythe. Additional cleanup operations included rock-picking, removal of debris and roots, and cultivation and harrowing.

Criteria for establishing sites along the pipeline laterals included accessibility, landowner co-operation, uniformity of topography and slope, and a lack of stones. All sites were established on cultivated lands and were chained-in a minimum of 60 m from the marker posts at a road crossing.

A single cylinder bulk density sampler was used to collect four soil samples at depths of 0-15, 15-30 and 30-45 cm on the trench, work side, spoil side and off right-of-way (field) locations (Figure 2). Soil samples were collected from six sites on the Gleichen Lateral, three sites on Mikwan, and four sites on the Hythe Lateral. The parameters used to assess soil quality included bulk density, texture, pH, EC, carbon content, calcium carbonate, and available nutrients (NH_4 , NO_3 , P, K). The four replicates of surface samples were analyzed individually, while replicates of the subsoils (15-30 and 30-45 cm) were bulked after bulk density determination, to produce a representative sample and to reduce the number of samples for analysis.

The experimental design used for this study was a split plot design; however, because the replicates of subsurface depths were bulked, a split plot statistical analysis could not be employed, and only the means of surface samples were used. This was done on the assumption that all values were determined with equal precision. Factorial techniques were employed in an analysis of variance between location, depth and site. Separate analyses of variance tests were also run for each soil parameter at each of the three depths. Significance between locations was determined using multiple two-tailed t-tests.

RESULTS AND DISCUSSION

This section is based on the presentation and discussion of mean values for the various soil parameters measured for the pipeline trench, working side, spoil side and the undisturbed field sites. More detailed information will be available later in 1983 in a report currently in preparation by NOVA.

No significant differences were found between bulk densities at on or off right-of-way locations at any of the three depths (Table 1). At

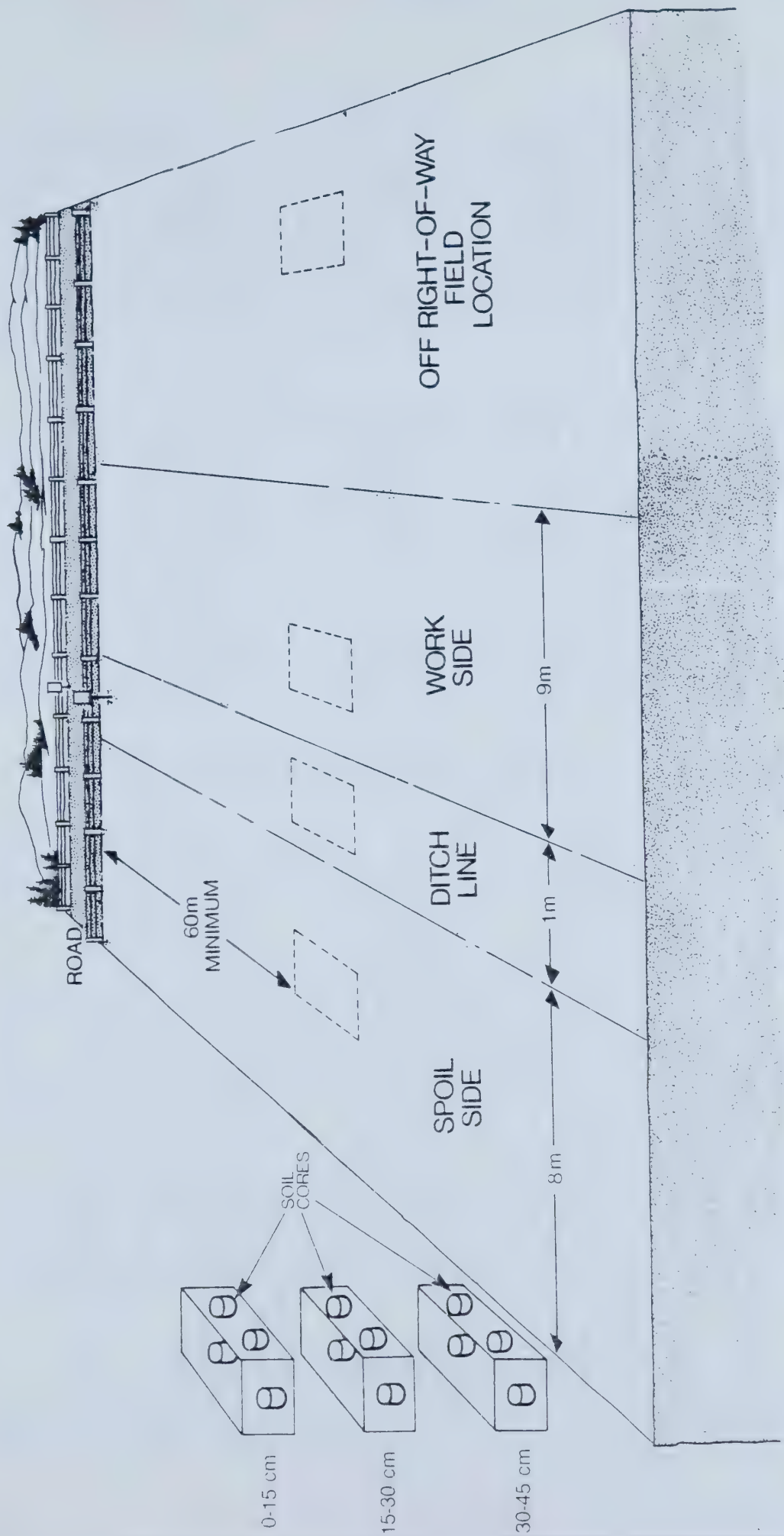


FIGURE 2: SCHEMATIC LAYOUT OF SOIL SAMPLING ON AND OFF RIGHT-OF-WAY AT EACH SITE

Table 1. Mean Values of Selected Soil Parameters at Three Depths On and Off Right-of-way Locations for All Sites.

LOCATION	SOIL PARAMETERS				
	Bulk Density (g/cm ³)	pH	EC (mS/cm)	Clay (%)	CaCO ₃ (%)
(0-15 cm) Trench Work Spoil Field	1.18 +*.20a**	7.5 + .3c	2.0 + 1.2b	31 + 10b	4.7 + 2.6b
	1.12 + .21a	6.7 + .7ab	0.5 + .3a	24 + 9ab	2.1 + .8a
	1.19 + .18a	7.1 + .5b	1.3 + .8b	22 + 6a	2.7 + 1.9a
	1.11 + .14a	6.4 + .8a	0.4 + .2a	23 + 9a	1.7 + .9a
(15-30 cm) Trench Work Spoil Field	1.34 + .13a	7.5 + .6b	2.1 + 1.4b	31 + 11a	4.7 + 2.7b
	1.34 + .11a	6.7 + .9a	0.4 + .2a	31 + 11a	2.9 + 2.3ab
	1.33 + .22a	6.7 + .7a	0.5 + .4a	28 + 12a	3.2 + 2.5ab
	1.34 + .12a	6.5 + .7a	0.3 + .2a	29 + 11a	2.5 + 2.0a
(30-45 cm) Trench Work Spoil Field	1.39 + .14a	7.3 + .9a	1.8 + 1.5b	32 + 10a	6.3 + 3.3a
	1.35 + .20a	6.9 + 1.2a	0.6 + .9a	36 + 13a	4.8 + 5.1a
	1.38 + .13a	6.7 + 1.3a	0.4 + .2a	41 + 15a	5.9 + 7.6a
	1.38 + .14a	6.7 + 1.2a	0.4 + .2a	39 + 13a	5.2 + 5.5a

* + standard deviation

** abc - numbers do not differ (P<0.05) if same letter

63,640 kg, the topsoil stripping machine is the heaviest single machine on the right-of-way, but the average ground pressure exerted by this piece of equipment is only 1.02 kg/cm² or 100 kilopascals (kPa) based on a track size of 69 cm by 452 cm. Peak pressures may exceed average ground pressure by 2.5 to 3 times (Byrnes et al., 1981). Conversely, a fully loaded flatbed truck with pipe exerts an average ground pressure of about 250 kPa, and is the heaviest piece of equipment in terms of ground pressure. However, use of the topsoil stripping machine and loaded flatbeds, plus pickups, graders, side boom tractors, etc., has not had an effect on bulk density or soil compaction.

Some chemical properties of the soil appear to have changed. The pH values in the top 15 cm of soil indicate that the trench has a significantly higher pH (7.5) than the other three locations, work, spoil and field (Table 1). This indicates subsoil mixing with the topsoil within the trench. Mixing may have occurred during final cleanup operations in late May or early June, or it is possible that the topsoil stripping machine went too deep in removing topsoil. The spoil location is also significantly different from the field for the 0-15 cm layer. This would appear to indicate that machine cleanup, the final operation of winter construction, was not totally successful in removing all spoil material from on top of the spoil side topsoil. At the 15-30 cm depth, only the trench pH was significantly different (pH 7.5) from the other three locations. At 30-45 cm there was no difference between any of the sites.

The electrical conductivity values (EC) also show some significant differences between trench and spoil locations versus work and field. At the trench location, the differences indicate topsoil/subsoil mixing which may have occurred during topsoil stripping in the winter or topsoil replacement in the late spring. For the spoil side, this would confirm that some spoil material was left at the surface. The trench was significantly different from the other locations at all three depths except for the 0-15 cm depth for spoil. It is important to note that the magnitude of the trench EC (2.1 mS/cm) would not affect the growth of normally-grown field crops (U.S.D.A., 1954). The highest single trench EC value recorded for a surface sample was 4.0 mS/cm at site G2 on the Gleichen Lateral. Topsoil at this particular site was not stripped at the landowner's request. In this case, the EC values appeared to be the only soil parameters adversely affected out of all the soil parameters measured. This was in relation to other locations and depths at the same site, or other sites on the same lateral.

Clay content at the trench location was significantly higher than the other three sites for the 0-15 cm depth. The work location was slightly higher in clay content, which could indicate that the topsoil removed from the trench had a higher clay content. This is likely due to the topsoil stripping machine operating too deeply, since mixing of topsoil and subsoil

during topsoil replacement would not be expected to produce this result. There were no significant differences in clay content at lower (15-30 and 30-45 cm) depths.

Calcium carbonate levels were significantly higher over the trench location at the 0-15 and 15-30 cm depths. This appears to indicate that subsoil/topsoil mixing was largely confined to the trench location as demonstrated by the soil chemistry.

Organic matter contents were found to be significantly lower over the trench than at the other three locations (Table 2). The spoil, field and work locations did not exhibit significantly different levels of organic matter content and, on the average, the reduction in organic matter was about 50% at the trench location.

Modulus of rupture, which provides a measure of crusting strength, was significantly higher at the trench location than at the other three locations. Spoil side values also tended to be higher, but not significantly, than those for the work and field locations. The modulus of rupture values of trench and spoil locations are still regarded as fair, however, and may not be detrimental to plant growth (Macyk, 1981).

Available nutrients were determined for the 0-15 cm depth samples, but the numbers obtained are of questionable value considering that spring fertilizing operations preceded final cleanup and sample collection. Ammonium, nitrate and potash levels are not significantly different, but are slightly lower at the trench and spoil locations than at the work and field locations. This could be due to a lack of fertilization at these sites or to a reduction in organic matter content which resulted in more nutrients leaching out of the soil profile or to an increase in clay content which rendered more nutrients unavailable. Phosphate levels do, however, show a significant decrease at the trench location with a secondary low on the spoil side of the right-of-way. This difference may be related to an increase in clay content.

The data indicate that there have been several significant changes in topsoil chemical and physical properties at the trench locations as opposed to the spoil, work or field locations. The significance of these differences in terms of whether there is actually a reduction of the capability of this small strip of soil, approximately 1 m in width, is currently unknown. Topsoil pH and EC values at the trench location would still be rated as good, while modulus of rupture and clay, calcium carbonate and organic matter contents would be rated as fair (Macyk, 1981). The soil quality of the spoil location has been reduced to a lesser degree. This indicates that some subsoil has been left on the surface of the spoil side of the right-of-way through incomplete subsoil replacement. Topsoil/subsoil mixing at the trench location could have occurred during topsoil

Table 2. Mean Values of Various Soil Parameters at the Surface of On and Off Right-of-way Locations for All Sites.

LOCATION	SOIL PARAMETERS					
	Organic Matter %	Modulus of Rupture (kPa)	Available Nutrients (ppm)			Potash
			Ammonium	Nitrate	Phosphate	
(0-15 cm)						
Trench	1.1 +* .3a**	151 + 73b	13 + 8a	18 + 17a	8 + 11a	242 + 156a
Work	2.2 + .7b	79 + 53a	15 + 11a	28 + 21a	22 + 13b	363 + 247a
Spoil	2.0 + .7b	109 + 70ab	14 + 11a	22 + 14a	14 + 9ab	263 + 154a
Field	2.5 + 1.0b	90 + 66a	16 + 12a	21 + 15a	21 + 15b	329 + 177a

* + standard deviation

** ab - numbers do not differ (P<0.05) if same letter

stripping operations or topsoil replacement in the summer. Since topsoil replacement was later than seeding, it was not possible to obtain comparative yields on and off right-of-way in 1982. These measurements, plus more soil sampling and analysis, will be done in 1983.

SUMMARY

Use of the topsoil stripping machine in winter construction restricted soil disturbance primarily to the trench or ditchline location on the right-of-way. There have been significant changes in the chemical and physical properties of the surface layer (0-15 cm). The effect of these changes on the soil capability over ditchline is not presently known, but further work is being done to investigate longer term effects on land productivity and capability.

There was no measured effect of winter construction or spring cleanup on soil compaction. It can be concluded that this method of pipeline construction is suitable for soils which are susceptible to compaction. These would include soils with a high clay or low organic matter content.

There was a slight reduction in soil quality on the spoil side of the right-of-way which may be related to incomplete subsoil removal from the surface of the spoil side during replacement. More attention should be paid to this particular operation of pipeline construction to maintain soil quality on the spoil side of the right-of-way.

ACKNOWLEDGEMENTS

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EFFECT OF TOPSOIL REPLACEMENT ON
SAND STABILIZATION AND REVEGETATION
IN THE
GREAT SAND HILLS OF SASKATCHEWAN

by

D.G. Walker, D.G. Paton, and J. Ashworth¹

ABSTRACT

A study on methods to stabilize and revegetate areas of high sand content soils was conducted on the route of the Alaska Highway Gas Pipeline Project in the Great Sand Hills of Saskatchewan. Results on the effect of simulated topsoil replacement and topsoil removal are reported. Lack of topsoil resulted in soil conditions detrimental to plant growth and susceptible to wind erosion. Without topsoil, there was an increase in bulk density, pH, and rate of cellulose decomposition. Percent carbon, nitrogen and water were lower in the section without topsoil. The average number of all native plants/m² was more than six times higher on the section with topsoil after 15 months and after 26 months ground cover was more than double. The section with topsoil recorded a much higher rate of establishment of revegetation plants (17 varieties tested) and better growth and reproductive capability. Fertilization with 50 kg-N/ha for 3 years did not mitigate the loss of topsoil as measured by forage production. Soil erosion losses were much higher throughout the period of the study and were still serious after 3 years on the section without topsoil while the section with topsoil appeared stable. Soil erosion losses were highest during late winter/early spring when snow and vegetative cover was minimal. Stabilization and revegetation procedures are more likely to succeed if performed in springtime rather than in fall.

¹ With, respectively, Walker & Associates Limited;
Nova, An Alberta Corporation (formerly with Norwest Soil Research Limited);
and Norwest Soil Research Limited.

INTRODUCTION

The Eastern Leg of the Alaska Highway Gas Pipeline Project begins in Central Alberta and leaves Canada near Monchy, Saskatchewan.

Environmental Concerns

Certain sections of the Eastern Leg route are recognized as being environmentally sensitive. In particular, the Great Sand Hills region of Saskatchewan is regarded as being ecologically unique and potentially difficult to revegetate after a surface disturbance (Epp and Townley-Smith (1979).

Climatic Constraints: The route in southern Saskatchewan crosses the driest region of the Canadian Prairies (Longley 1972). Long-term average rainfall is between 130 and 150 mm during the growing period, June to August. The number of days with a maximum temperature above 26°C is 55, compared to Edmonton with less than 18. Storm systems with high winds are frequent (Longley 1972) and conducive to high evaporation rates and wind erosion. Maximum wind speeds are predominately from the south and southwest and occur most frequently during April-May and again in October when vegetative and snow cover is minimal. There is a 1 in 10 year probability of maximum wind speeds in excess of 100 km/hr.

Soil Limitations: In addition to the climatic constraints prevalent along the Eastern Leg route, soils also present revegetation difficulties. High sand-content soils are located in Alberta west of Empress in the Middle Sand Hills and north of Brooks near the Wintering Hills, and in Saskatchewan north of Maple Creek in the Great Sand Hills. Wind erosion of sandy soils results in blowouts and large moving dune complexes. Observations of previous disturbances suggest that permanent stabilization of these soils is often difficult and expensive. Repeated grading, seeding, and stabilization efforts are often required to stop the movement of sand.

Sand Stabilization and Revegetation Studies

Sponsors of the Alaska Highway Gas Pipeline Project contracted Walker & Associates Limited to investigate methods of stabilizing and revegetating sandy soils. Soil nutrients studies conducted by Norwest Soil Research Limited and microclimatic studies conducted by Campbell Scientific Canada Corporation were other aspects of the investigation.

METHODS

Test plots were established in May, 1980 on a 1 ha site in the Great Sands Hills, 20 km north of Maple Creek, Saskatchewan. Only the methods pertinent to the results reported in this paper are described.

Experimental Design and Analysis

Ground Preparation: In order to simulate the conditions resulting from topsoil salvage and replacement, the top 15 cm of the soil profile on a 15 by 130 m piece of native prairie was cultivated with repeated passes of a large agricultural breaking disc. This represents an optimal soil condition in which all the topsoil has been removed and replaced without dilution to the same location and seeds of native species remain near the soil surface. In practice, topsoil stripping results in considerable mixing of the profile and some loss of topsoil material in low-lying areas inaccessible to the grader blade.

Topsoil was removed with a large earthmover on a second adjacent piece of native prairie also 15 by 130 m. The top 15 cm was stripped and the exposed subsoil was cultivated with a breaking disc to level the ground and dry out the soil. This represents a difficult soil condition where most of the organic matter, rootstalks and seeds of native species, and microbiota in the upper soil profile are missing. Active sand dunes present the most difficult soil condition for revegetation because the silt and clay content is very low and vegetation is "sand-blasted" by accelerated wind speeds in the bowl.

Design and Analysis: The design of the study was such that two separate experiments (ground preparations) were placed side by side with a 5 m buffer between. Sets of treatments were applied to each ground preparation in an identical manner. The number of replications of each of the sets of treatments varied according to the desired level of confidence, expected variability of data, and time and space constraints. Statistical analysis of data was conducted when interpretation of results could be improved with an appropriate test of validity. Analysis of variance was used to compare differences between treatments within experiments and various T-tests were used to compare differences between experiments.

Soils Methods

Analytical Methods: Total N was measured by Kjeldahl digestion, followed by distillation and titration of $\text{NH}_4\text{-N}$ (ammonium-N); total carbon was measured by a Walkley-Black procedure in which carbon is oxidized by chromic acid and excess acid is back-titrated with FeSO_4 solution. Mineralizable N in soil organic matter was measured by the method of Waring and Bremner in which soil (4 g) is added to deionized water (10 ml) and incubated anaerobically at 30°C in stoppered tubes. The mixture was made 1M in KCl after 10 days, shaken and allowed to stand before measuring $\text{NH}_4\text{-N}$ in the supernatant solution by a routine, automated method. $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ were measured in an extract of soil

obtained by shaking with KCl solution and then filtering the mixture. Available P₀₄-P was measured by extraction with ammonium fluoride, exchangeable K by extraction with ammonium acetate, and S₀₄-S by extraction with CaCl₂ solution.

Fertilizer Response: Nitrogen (50% from calcium nitrate and 50% from urea) was applied at a rate of 50 kg-N/ha by broadcast method in early June. Forage production was measured by clipping paired plots (0.1 m²) in August.

Soil Samples: Soil samples were taken in June (prior to fertilization) and on three other dates to 15 cm depth by Oakfield sampler or "Dutch" auger. Samples from 6 to 8 points per plot were mixed together and a representative sub-sample taken.

Cellulose Decomposition: The cellulose decomposition experiment was begun in late June to obtain a simple index of soil biological activity on sections with and without topsoil. Filter papers (Whatman No. 42, 7 cm dia.) were enclosed in plastic mesh and buried vertically next to a marker. All the papers were retrieved in late October (at which time they were still completely buried) and their residual weight determined.

Nitrogen Leaching: The leaching experiment, intended to follow the movement of nitrate within 1 m of the soil surface, was conducted in pairs of plots measuring 2 x 2 m in an area maintained free of vegetation. Paired plots were treated at a rate of 100 kg N/ha as either ammonium sulphate or ammonium nitrate. Samples were taken by Dutch auger at 4 points to 15 cm and then to 30 cm. At one of these points, samples were taken to 60 and then to 90 cm.

Vegetation Methods

Native Species: Invasion of native species was measured by plant count in a 1 m² sampling quadrat. Growth was measured by the line intercept method has been expressed as percent ground cover. Two intercepts, each fifteen meters long, were examined in each of three replications of the check plots (no seed or erosion control treatment) in the topsoil removed and topsoil replaced sections.

Revegetation Species: Success of introduced species was measured by percent establishment, survival, growth, and ability to set seed. Six replications of seventeen species of grasses and legumes were planted in 1.0 m rows 0.5 m apart on each of the topsoil removed and topsoil replaced sections. One hundred seeds were hand-planted per row; the method simulated drill seeding. Seedlings were counted to determine rate of establishment and survival. Height, percent cover, and seed production, were measured to determine growth and adaptability. The varieties were also seeded as a mixture at a rate of 10 kg/ha in plots and forage production was measured with and without nitrogen fertilizer.

Soil Erosion Methods

The amount of soil movement was measured by the following method. At the beginning of the study, pairs of 50 cm steel rods were placed 1 m apart in the ground so that exactly 15 cm was left above the soil surface. Four pairs were randomly located within each of the treatment plots on the topsoil removed and topsoil replaced sections. Sand movement was determined with an erosion metering device consisting of a row of dowels, each 20 cm long and 1 cm in diameter, attached to a 1.05 m wide board onto which a grid of reference lines had been inscribed. The board was set on the pairs of rods and the dowels were allowed to drop to the soil surface. The profile of the soil surface, reflected by the top of the dowels against the grid, was photographed three times per year (June, August, October). Determination of the volume of soil movement was made by measuring the area of the photographic print outlined by the dowels using an electronic planimeter. Calibration was accomplished by measuring the grid itself. The area, in square cm, multiplied by the dowel diameter (1 cm) yielded the volume of soil lost or gained during each time period. Bulk density measurements of the soil were used to calculate the weight. Rate of soil movement has been expressed as metric tonnes per hectare per time period. More than 500 photographs were measured over three growing seasons (1980-1982).

RESULTS AND DISCUSSION

Soils Results

Soils of the Area: The soils at the study site have been mapped as dune sands and undifferentiated sands that are considered to be unconsolidate surficial deposits rather than soils. Upon inspection, the soil was classified as an Orthic Brown Regosol with a very thin Ah horizon. Results from a routine analysis are contained in Table 1.

Table 1. Analysis of Orthic Brown Regosol from NW-11-14-25-W3.

pH	EC	%CO ₃	Available Nutrients (ppm)				
			NH ₄	NO ₃	P	K	S
8.7	0.11	0.22	5.4	3.0	2	125	3
Available Water (%)			Exchangeable Cations (meq/100g)				
-1/3 bars	-15 bars		TEC	Ca	Mg	Na	K
5.1	4.1		4.2	18.6	1.9	.04	.05

The soil was alkaline, low in soluble salts, low in nutrient status with very low moisture holding capacity. The high value for exchangeable calcium reflected the presence of free calcium carbonates. The values for available potassium were adequate. One of the biggest problems for plant growth with this soil is that it is rapidly drained with low moisture retention of only 1% available water. It should be noted, however, that the grinding and sample preparation may have eliminated some organic matter such as roots and stems which would certainly improve the moisture holding capacity.

Particle Size: Soil (100 g) from the leaching experiment was shaken in a nest of sieves and each fraction weighed (Table 2). The bulk of soil consisted of fine and medium sand, with a little more coarse sand in the topsoil removed section than in the topsoil replaced section. Because it lacks a significant clay or silt component, soil of this texture is more prone than any other to wind erosion, and the risk is acute in areas like southwestern Saskatchewan where moisture deficits are severe and average wind speeds are high.

Table 2. % soil particles in stated size-range (mm).

	>1.0	1.0- 0.5	0.5- 0.25	0.25- 0.105	0.105- 0.053	<0.053
		Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt +Clay
<u>Topsoil Replaced</u>						
0-15 cm	0.6	6.8	46.4	42.6	2.9	0.2
15-30 cm	1.0	8.4	47.4	40.2	2.6	0.1
<u>Topsoil Removed</u>						
0-15 cm	0.5	6.5	48.5	41.4	3.1	0.2
15-30 cm	1.5	20.1	50.0	26.3	1.6	0.1

Soil Organic Matter: Soil sampled in June from two replicates was analyzed for % N and % C; these properties change only gradually over a period of years (Table 3). Soil moisture content, which is subject to much more rapid change, was also measured.

Straw fragments inadvertently included with the soil sample introduce C and N out of proportion to their weight and probably were responsible for the poor agreement between some duplicates; in these cases, the lower figure is likely to be the more trustworthy. The results might have been smoothed by preliminary sieving but the removal of small particles of organic matter could have obscured the effects of the revegetation treatments. The % C and % N are markedly less in the topsoil removed section.

These parameters indicate the size of the pool of soil organic matter, which affects the soil's physical structure, density and moisture-holding capacity as well as fertility. In comparison with most agricultural soils of

Table 3. % Carbon, nitrogen and moisture in soil.

	% C		% N		% H ₂ O	
	RepI	RepII	RepI	RepII	RepI	RepII
Topsoil Replaced	0.60	1.06	0.09	0.06	6.5	8.1
Topsoil Removed	0.29	0.26	0.03	N/A	5.6	6.2

the prairies, the soil at the experimental site has very little organic matter and the effect of not replacing topsoil is to leave a soil extremely deficient in C and N, with correspondingly poor physical structure, impaired water-holding capacity and nutrient availability.

Mineralizable Nitrogen: Mineralizable nitrogen is the fraction of total N made available to plants through bacterial degradation of organic matter. The results (Table 4) are consistent with the C and N contents of the soils; soil from the topsoil replaced sections mineralized more N than soil from the topsoil removed section.

Table 4. Nitrogen present (mg NH₄-N/kg soil) after anaerobic incubation at 30°C for 10 days.

	Rep I	Rep II
Topsoil Replaced	37	36
Topsoil Removed	10	29

The results indicate relative N-supplying power and the magnitude of the reserve of N even where topsoil and much associated organic matter had been removed. If the N (0.06%) that is present in the soil became available by gradual mineralization, there would be enough to provide 30 kg-N/ha annually for the next 40 years. The supply, in fact, is inexhaustible because of continual inputs of N to the natural cycle, mainly through fixation of atmospheric nitrogen by legumes.

Bulk Density: Known volumes of soil were removed in triplicate from each section and their dry weight was measured in the laboratory. The results (Table 5) show that, on the topsoil removed section, the remaining soil now near the surface is more dense. This is another factor detrimental to regrowth where topsoil had been removed, and is probably associated with the lowered organic matter content.

Table 5. Bulk density of soil (g/cm³).

Topsoil Replaced	1.52 ± 0.06
Topsoil Removed	1.76 ± 0.12

Cellulose Decomposition: The change in weight (Table 6), representing bacterial degradation during a 4 month period of exposure in topsoil, was determined by subtracting the residual weight from the average weight of one No. 42 filter paper disc.

Table 6. Change in weight of filter papers exposed in soil from June 29 to October 23.

Topsoil Replaced	0.116 ± 0.033
Topsoil Removed	0.199 ± 0.026

Surprisingly, the results show that cellulose-decomposing bacteria had, in general, been most active in soil on the topsoil removed section. Lack of competition for the cellulose-decomposing bacteria from other microorganisms or higher soil temperatures may be a partial explanation. It is possible to interpret this result as encouraging by suggesting that the microbial population is actively engaged in forming a new Ah horizon to replace the one removed. A less sanguine view is that organic matter will take a very long time to recover its previous equilibrium, in the face of the high rate of decomposition.

Since the soil at the site was formed under climatic conditions similar to those prevailing today, the topsoil removed section will probably ultimately revert to its previous condition. However, soil formation is so slow that, for practical purposes, it is probably correct to conclude that the soil has been adversely affected on a permanent basis.

Nitrogen Leaching: The results of analyses for NH₄-N and NO₃-N on one of the three dates sampled are presented in Figures 1 & 2 which show changes in amounts of the two forms of nitrogen descending into the soil profile. There was very little change in distribution of nitrate over the period of investigation. On the topsoil replaced section, concentrations fell from 10-20 ppm near the surface to approximately 5 ppm, 60-90 cm down. Concentrations were less throughout the profile on the topsoil removed section, suggesting that much of the nitrate found had been derived from soil organic matter.

There was no evidence of "peaks" of nitrate concentration moving down the profile, which suggests that nitrate leaching is not an important mechanism in loss of nitrogen from the system. This conclusion is supported by the results of measuring soil moisture content, which in summer rarely exceeded 5.1%.

Denitrification losses from the system are also unlikely to have occurred because this would have produced a different distribution of nitrate from that observed, namely one in which nitrate concentrations increased with depth.

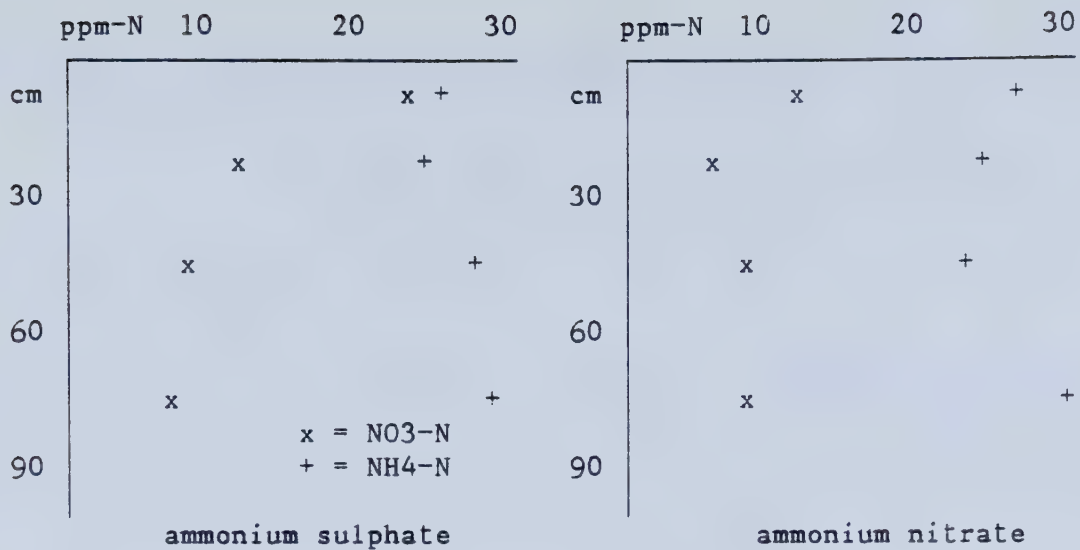


Figure 1. Extractable N (ppm) in leaching experiment at various depths (cm) on Topsoil Replaced section, August 5.

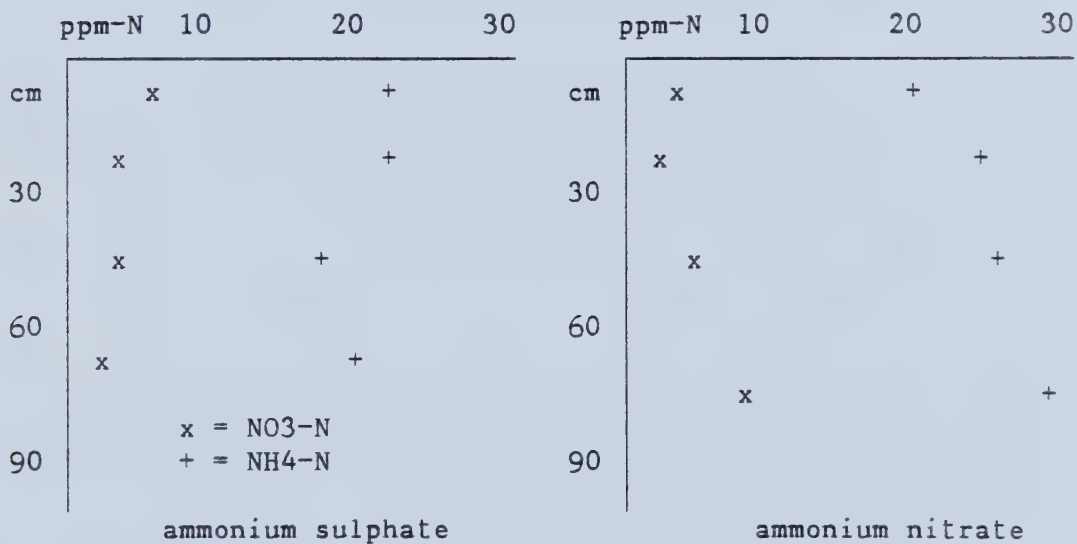


Figure 2. Extractable N (ppm) in leaching experiment at various depths (cm) on Topsoil Removed section, August 5.

The highest concentrations of NH₄-N were found in samples taken on August 5 (Figures 1 and 2). Concentrations found on June 29 were unexpectedly small in view of the large dressing of fertilizer applied four weeks previously. Most of the NH₄-N present on August 5 had disappeared by October 23.

The unexpectedly small recovery of NH₄-N on June 29 strongly suggests that most of the applied NH₄-N was lost by volatilization of NH₃. If this is true, the large concentrations of NH₄-N found on August 5 must be due to mineralization of soil organic matter. Because plants were virtually absent on the leaching experiment, continuing volatilization losses were presumably responsible for the disappearance of a considerable portion of this NH₄-N between August 5 and October 23. This conclusion is consistent with the larger

concentrations of $\text{NH}_4\text{-N}$ found in the subsoil on the latter date, compared with concentrations nearer the surface.

The results do not support the alternative view that nitrification, followed by nitrate leaching, was the main mechanism of loss. Losses of NH_3 are to be expected from soils with a pH of 8 because, although the equilibrium in the equation $\text{NH}_4^+ + \text{OH}^- = \text{NH}_3 + \text{H}_2\text{O}$ lies to the left at pH less than 9, the constant evaporation of NH_3 causes further dissociation of NH_4^+ in order to try to maintain the appreciable equilibrium concentration of NH_3 . The results obtained suggest that any ammonium fertilizer (especially urea, which hydrolyzes to NH_3 with an accompanying rise in soil pH) will be inefficient on this soil.

Vegetation Results

Native Species: The invasion or reestablishment of native species was measured on check plots (no seeding or erosion control treatment). Results of the analysis of native species is summarized in Table 7.

Table 7. Total native species in untreated plots.

Parameter	Time	Topsoil: Replaced	Removed
plants/m ²	after 3 mo.	9.9	<0.1
	after 15 mo.	31.5	5.0
plants % cover	after 26 mo.	49.9	25.7
litter % cover	after 26 mo.	13.6	5.4

Total plant cover of native species in the topsoil replaced section (49.9%) compares favorably after 26 months with that in the adjacent native prairie which was found to be 55.3%. The lower plant cover in the topsoil removed section (25.7%) illustrates the importance of topsoil as a seed source of native species as well as creating an environment less hostile to plant establishment (see results on soil erosion).

Revegetation Species: Seedling establishment after one season was measured by counting the number of seedlings of 17 varieties sown in rows maintained free from competing vegetation (summary in Table 8). The subsequent performance of each variety is illustrated in Tables 9 and 10.

Table 8. Average number of seedlings per gram of seed of seventeen varieties after one growing season.

Topsoil Replaced	983
Topsoil Removed	233

Table 9. Species performance after 15 months: % cover, height and reproduction, Topsoil Replaced section.

Species	cover(%)	ht (cm)	heads	seeds
Critana thickspike wheatgrass	100.0± 0.0	37± 2.5	Yes	Yes
Sodar streambank wheatgrass	92.5± 8.3	29± 2.2	Yes	Yes
Greenleaf pubescent wheatgrass	90.0±10.6	39± 2.5	Yes	Yes
Parkway crested wheatgrass	87.5± 9.0	41± 5.4	Yes	Yes
Durar hard sheep fescue	85.0±12.7	18± 2.5	Yes	Yes
Orbit tall wheatgrass	85.0±15.4	31± 8.9	Yes	Yes
Revenue slender wheatgrass	83.8±20.4	58±22.5	Yes	Yes
Sawki Russian wild ryegrass	77.5±18.2	20± 3.5	No	
Lodorm green needlegrass	76.2±26.8	31± 2.2	Yes	Yes
Prairieland Altai wild ryegrass	75.0±30.6	30± 6.1	Yes	Yes
Rambler alfalfa	71.2±12.9	15± 0.0	No	
Rosana western wheatgrass	65.0±10.6	28± 2.5	Yes	No
Sherman big bluegrass	52.5±26.6	24± 4.1	Yes	Yes
Oxley cicer milkvetch	51.2±19.5	10± 0.0	No	
Reubens Canada bluegrass	22.5±17.5	19± 5.4	Yes	Yes
Melrose sainfoin	15.0±20.3	14± 6.2	Yes	Yes
Goshen prairie sandreed	12.5± 9.0	14± 2.4	No	
Average	67.2 %	27 cm		

Table 10. Species performance after 15 months: % cover and height, Topsoil Removed section.

Species	cover(%)	ht (cm)	heads
Sodar streambank wheatgrass	38.8±38.8	11±1.2	no
Prairieland Altai wild ryegrass	18.8±32.5	15±0.0	no
Lodorm green needlegrass	16.2±25.3	10±5.0	no
Durar hard sheep fescue	6.2± 4.1	6±1.2	no
Orbit tall wheatgrass	6.2±10.8	10±0.0	no
Rambler alfalfa	5.0± 6.1	6±1.2	no
Oxley cicer milkvetch	3.8± 4.1	10±0.0	no
Greenleaf pubescent wheatgrass	1.2± 2.2	15±0.0	no
Revenue slender wheatgrass	dead		
Melrose sainfoin	dead		
Sherman big bluegrass	dead		
Critana northern wheatgrass	dead		
Rosana western wheatgrass	dead		
Parkway crested wheatgrass	dead		
Sawki Russian wild ryegrass	dead		
Reubens Canada bluegrass	dead		
Goshen prairie sandreed	dead		
Average of live species	12.0 %	10.4 cm	

By the end of one growing season, more than 4 times as many plants were established per gram of seed sown. Results from Tables 9 and 10 indicate that topsoil replacement also had a great effect on survival, growth (cover and height), and ability to flower of the varieties. None of the varieties flowered on the topsoil removed section while 13 varieties flowered and 12 produced seed on the topsoil replaced section. Five times more cover was produced on the topsoil replaced section than on the topsoil removed section. While plants of all 17 varieties survived on the topsoil replaced section, only eight varieties survived after 15 months on the topsoil removed section. Average plant height was three times higher on the topsoil replaced section (27 vs. 10 cm).

Results in Tables 9 and 10 rank varieties in order of successful growth under test conditions consisting of single species planted in rows maintained free of competitors. Other tests conducted with the varieties as part of the study but not described here, indicated a somewhat different ranking of varieties. For example, Critana thickspike wheatgrass was not competitive with other species and was therefore much less successful when seeded in plots with a mixture. Alfalfa, on the other hand, was more successful when seeded in a mixture because of less grazing by rodents. Prairie sandreed is one of the most common native grass species of the Great Sand Hills region yet a commercially available variety failed. The lack of success of Goshen prairie sandreed grass, a licenced native species from Wyoming, illustrates that some native species may only be adapted to local regions.

Assessment of forage production on both ground preparations included both revegetation and native species and was determined by clipping paired samples from seeded plots fertilized at 50 kg/ha/yr for three years and from adjacent native prairie (Table 11).

Table 11. Effect of topsoil replacement and 3 years of fertilization on forage production (g/0.1m²).

	50 kg-N/ha/yr	0 kg-N/ha/yr
Topsoil Replaced	23.5 ± 5.5	15.7 ± 5.5
Topsoil Removed	13.8 ± 3.7	3.4 ± 0.7
Ungrazed Prairie		11.0 ± 2.0

Results indicate that three consecutive years of applying 50 kg/ha of nitrogen did not mitigate loss of topsoil. Unfertilized plots with topsoil produced more forage (15.7) than fertilized plots without topsoil (13.8). The former, in fact, were more productive than ungrazed prairie within the test plot enclosure (11.0) attributable in part to a difference in species composition. The results confirm laboratory findings that mineralization of soil organic matter can be a significant source of nitrogen for plant growth.

Soil Erosion Results

Results of monitoring soil movement (Table 12) illustrate the importance of topsoil replacement on stabilizing the movement of soil by wind erosion (150 t/ha is equivalent to 1 cm of soil).

Table 12. Soil movement (t/ha) on topsoil replaced and topsoil removed sections over 29 months.

Time Period	Topsoil Replaced	Topsoil Removed
Jun to Aug 1980	+24	- 32
Aug to Oct 1980	+97	+ 26
Oct to Apr 1981	-65	-103
Apr to Aug 1981	+22	- 84
Aug to Oct 1981	+56	+ 21
Oct to Jun 1982	+12	- 4
Jun to Aug 1982	+13	- 49
Aug to Oct 1982	+36	+ 20

The topsoil replaced section recorded a net loss only during the first winter period after disturbance. The 1981 winter on the praires was notable for record high temperatures, very low precipitation levels, and frequent periods of high winds - conditions conducive to severe wind erosion. Soil losses tend to be greatest during winter and spring when vegetative cover is least while soil gains were generally recorded during the August to October period when cover is at a maximum. In the hot, arid climate of this region, plant establishment is most successful in springtime and the continuing loss of material on the topsoil removed section exacerbates an already difficult soil condition. The section without topsoil recorded a net loss of soil during the most recent year of monitoring and is not stable. The section with topsoil has not recorded a net soil loss for 18 months and appears stable and vegetated.

Results from other aspects of the sand stabilization and revegetation studies suggest that the amount of soil movement is dependent on size of the disturbed area. Study plots were small in comparison to the size of right-of-way required for pipeline construction. For this reason, the amount of soil movement should be considered to be a conservative estimate.

CONCLUSIONS

The Great Sand Hills region in Saskatchewan is potentially very difficult to revegetate after a surface disturbance such as pipeline construction. Climatic constraints on plant growth consist of low precipitation levels, frequent high winds, and high average temperatures. Soil characteristics also pose serious limitations to plant growth. The major one is the low water-holding capacity resulting from the coarse texture of the soil and low

organic matter content. Furthermore, almost 90% of the soil particles are in the size range most susceptible to wind erosion (0.1-0.5 mm).

Changes in the character of the soil through loss of topsoil were detrimental to plant establishment and growth. Loss of topsoil resulted in an increase in bulk density, pH, and rate of cellulose decomposition. Loss of topsoil decreased organic matter content and hence water-holding capacity; susceptibility to drought and wind erosion increased.

Topsoil replacement provides a ready source of seeds and rootstalks of indigenous native species. Compared to the section without topsoil, the section with topsoil had more than six times the number of native plants after 15 months and more than twice the ground cover after 27 months. With topsoil, there was a five-fold difference in the average number of plants established per gram of seed of 17 revegetation varieties. Percent cover, height, and reproductive success of the revegetation varieties were all much higher on the section with topsoil.

Forage production on the unfertilized section with topsoil was better than the adjacent native prairie and also better than the no topsoil section fertilized for three years. Soil losses continue to be recorded on the section without topsoil after 29 months while the section with topsoil continues to gain. The most serious erosion losses were recorded in the time period when vegetative and snow cover is minimal (late winter, early spring). This suggests stabilization and revegetation are more likely to succeed if performed in spring rather than fall.

ACKNOWLEDGEMENT

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RECLAMATION OF WELL SITES AND ACCESS ROADS
IN AN AGRICULTURAL ENVIRONMENT

BY

Walter L. McNary, P. Ag.¹

ABSTRACT

The reclamation of well sites and access roads on agricultural lands presents a challenge to those involved. Voyager Petroleums activities in the main in Alberta cover about 6,500 square miles in an area from Lamont in the north to Buffalo Lake in the south and east to the Saskatchewan border. All of this land is in an agricultural environment covering the broad spectrum of farming operations including grain farming, ranching, and concentrated livestock operations.

The area includes deep and shallow black, solodic, solonetz, and greywooded soils. Reclamation of well sites and access roads to comparable agricultural capability of surrounding lands continues to be a challenge.

This presentation provides an overview of Voyager Petroleums present methodology in their reclamation activities with some discussion on new processes which are being tried.

RECLAMATION OF WELL SITES AND ACCESS ROADS
IN AN AGRICULTURAL ENVIRONMENT

Voyager Petroleums finds that reclamation of well sites and access roads ideally begins with the taking of a lease. If the proposed well site or access road is so located that it cuts a body of water or a water runway the landman should check with the company to determine if the site can be moved. Many times a small move at this time will prevent serious reclamation problems in the future. Reclaiming a water course is extremely difficult, due to the hazards of continuing erosion.

Similarly access roads built through sloughs cause severe reclamation difficulties. While it is recognized that many farmers would prefer access roads and well sites on unfarmable land, it is the responsibility of the landman to explain the implications involved in reclamation.

In the preparation of well sites prior to drilling it is imperative that the topsoil is stripped and piled to the edge of the lease in such a manner it does not block normal water runoff. Our company has found it is better not to strip the access prior to drilling. Should the well not prove to be a potential producer, stripping the access causes unnecessary reclamation procedures. Ofttimes a potential producer may not be put into production for a year or so after drilling and an access road is not necessary until it is put on stream.

¹ Landman, Voyager Petroleums Ltd., Camrose, Alberta

Prior to building an access road, the topsoil should be stripped back to the side of the access and later used to back slope the ditches along the access road. Our access roads are fifteen metres wide, in order to facilitate a good job of road building and final reclamation procedures. Our well sites are now one hundred ten metres square. We have increased the width of our access roads and size of well sites in recent years to facilitate easier site construction and reclamation.

Prior to any soil reclamation on a well site, all refuse such as pipe ends, cables, etc., which would be hazardous to cultivation are removed. All buried lines must be well below cultivation depths or removed.

Reclamation of a well site after drilling, begins with the squeezing of the drilling sump. This is done when the site is dry so that when the fluids from the sump are spread out on the site they will dry quite quickly. In many cases we would prefer to suck these fluids out when they contain no toxic materials and spread them in an area agreeable with the farmer. Well sites could then be reclaimed more quickly thus causing fewer weed problems etc. However, at the present time it is difficult to get a permit from the ERCB in order to remove fluids from the site.

Refilling the sump with subsoil is done evenly, with as much packing as possible so that there is little settling in the future. The site is then contoured to fit back in with the contour of the land, prior to putting the topsoil back in place. In order to minimize depressions in crop production following reclamation, deep ripping of the site prior to putting the topsoil back would appear to be a recommended practice on many of the soils in north eastern Alberta. Many of these soils are high in sodium and have a natural tendency towards developing a hard pan. Deep ripping to a depth of 36 inches is a process we are initiating on soils where subsoil compaction is a problem.

After the topsoil has been evenly distributed over the site two cultivations with a heavy duty cultivator finishes off the reclamation process unless there are rocks to be picked or the site has to be seeded down to grass.

When the well site is in a pasture area the same reclamation process takes place, plus some additional steps. Following cultivation the site is harrowed at least twice. A grass mixture agreeable to the farmer and at least certified Canada # 1 is broadcast, seeded by drill and packers or with a Brillion seeder. In many cases we have the farmer involved do the seeding. On the black soils it is imperative that the site is firmly packed prior to seeding if a good stand is expected. A good rule of thumb is that the soil should be packed so that you will not make a depression greater than the depth of the sole of your shoe when walking on it.

When the site is in an area where cattle are grazing the site should be fenced to keep cattle out until a good stand of grass is assured.

In the reclamation of access roads the reverse process of road building is used. The portion of access from road shoulder to access boundary is stripped of topsoil, and the road is levelled out in the area exposed. Here again, deep ripping of the levelled area is often beneficial prior to putting the topsoil back in place. After replacement of topsoil the area is then cultivated and harrowed. If the area is to be seeded down the same process is used as is done on the well site. When the access goes through a wet area, excess water should be pumped off and the site should not be reclaimed until the area is dry.

Although the forementioned is the general process for well site and access road reclamation there are always some exceptions. Frequently, a site has to be reclaimed which was not built properly prior to well drilling.

This is usually the case where wells were drilled several years ago and have ceased to be producers. In many of these cases the topsoil was not kept separate and the site was just levelled. From visual inspection it is apparent that if the site is to be reclaimed to an agriculturally productive state extra effort is necessary. In many cases up to 20 tons of manure per hectare are needed following the standard reclamation process. Care must be taken to ensure that the manure used is free from weed seeds not found in the area. It is preferable to use manure from the same farm as where the site is located. Following the application of manure, deep ripping and further cultivation is preferred.

In some situations where there has been a history of severe oil spills or other contaminants on the site some of the soil should be removed and hauled to an approved dumping area prior to the levelling and reclamation process.

After we have reclaimed a well site and access road to our satisfaction the land owner and occupant (if there is one) are contacted. If satisfied, a release is obtained. If they are not satisfied further processes may be necessary. Following the obtaining of a release an application is made to the Alberta Environment Reclamation Council for a Reclamation Certificate. The Reclamation Officer for the district involved then makes an inspection of the site. If he finds the site satisfactory he will recommend a Reclamation Certificate be issued. If some work still needs to be done he will recommend a Reclamation Order. Until such time as the site is in satisfactory condition no Reclamation Certificate is issued.

In most instances our company does not request a release from the land owner until we see the reclaimed site is producing. Our experience has been that the Reclamation Officer from the Reclamation Council will not provide a Reclamation Certificate until the site has been observed during the growing season.

In Voyager's years of site preparation and reclamation we have found that it is imperative to have good communications between the operators of the equipment and our supervisor. Continuity of use of certain construction firms has assured us of standardized procedures and high standards of reclamation.

In conclusion, I would re-affirm my earlier comments by emphasizing that reclamation begins at the time the sites are built. Unless this is done in a systematic manner, reclamation is very difficult and expensive to all concerned.

I would welcome further discussion on this subject, which is very important to the agricultural producers of Alberta.

RECLAMATION RESEARCH ON SYNCRUDE'S TAILINGS DYKE

by

T.S. Dai, M. Fung, K.P. McCumber and S.A. McKinnon
Environmental Affairs, Syncrude Canada Ltd.
10030 - 107 Street, Edmonton, Alberta T5J 3E5

ABSTRACT

Six reclamation research projects were implemented in 1981 and 1982 on Syncrude's tailings dyke slopes. The main objective is to develop revegetation and reforestation strategies and techniques to reclaim these slopes. For revegetation, the tests involve mechanically manipulating herbaceous vegetation by drill and/or broadcast seeding at various rates either in strips or over the entire area. The purpose is to develop a ground cover pattern that offers growing space for woody seedlings to become established while at the same time preventing soil erosion. The use of herbicides to create vegetation-free strips for the same purpose is also being investigated. For reforestation, investigations are being made regarding the performance of various planting stock sizes on the revegetated tailings dyke and the effect of planting time on seedling survival and growth.

INTRODUCTION

All process waters produced at the Syncrude oil sands project are retained on site. This has led to the formation of a tailings pond. The pond is designed to ultimately encompass an area of about 22 km² at an elevation of 347 m (average depth of about 30 m). It is located at the northern part of Lease 17, formerly known as the Beaver Creek valley. Since the pond is built above grade, it must be enclosed by a system of dykes. The dykes are constructed of compacted tailings sand delivered by pipelines from the extraction plant to the pond. Construction of the dyke is expected to continue until completion in 1987.

The dykes are designed to consist of several lifts depending upon the terrain at various locations. The first lift of the eastern and northeastern sections of the dyke was turned over for reclamation in 1981 and 1982. Our reclamation research team took this opportunity to initiate several research projects to develop techniques for sloped tailings sand reclamation. The objectives of these projects are two fold: (1) to establish adequate erosion controlling ground cover, and (2) to develop techniques to promote woody plant establishment. Our final goal for the dyke slopes is the establishment of terrestrial ecosystems which are erosion-controlling, self-maintaining and suitable for wildlife habitats.

The purpose of this paper is to outline our ongoing research projects on the tailings dyke. These projects can be organized into 2 categories: revegetation and reforestation. Revegetation studies include the Drill-seeding, Strip-seeding and Legume Inoculation projects; while reforestation studies include the Pre-planting Herbicide, Stock Size and Planting Time projects.

REVEGETATION RESEARCH

Drill-seeding Project

This study was initiated in 1981 to evaluate the use of seeding techniques, seeding rates and fertilizer rates for controlling the density and species composition of ground cover on the tailings sand dyke. The effects of ground vegetation cover density on the establishment and performance of woody species are also being evaluated.

The tailings dyke slope of Cell 24 was subdivided into 6 large blocks, each approximately 0.5 ha in size. Each block was seeded with grasses and legumes, either hand broadcasted or drill seeded, at one of three seeding rates in June 1981. Four shrub species; green alder, saskatoon, caragana and dogwood were planted in October 1981.

Ground vegetation cover was assessed in late July, 1982 for species composition and percent cover. All blocks have established a heavy vegetative cover. Among the seeded species, slender and crested wheatgrasses were the dominant grasses. Alfalfa was the dominant legume in all blocks.

The biomass of herbaceous plants ranged from 2000 to 3400 kg/ha on the drill seeding blocks and from 1100 to 2300 kg/ha on the Broadcast seeding blocks. Drill seeding produced a more uniform vegetative cover with more vigorous plants than broadcast seeding despite the lower seeding rates used.

The survival of woody seedlings was assessed in early June and late September, 1982. Caragana had the best survival rate among the four species planted followed by buffaloberry, dogwood and green alder. As of fall, 1982, one year after planting, caragana had a greater than 70% survival rate, while the other three species had less than 20% survival in most treatments. After two growing seasons with this experiment, several trends are shown from results collected to date:

- Grasses and legumes have become well established resulting in a heavy cover density in all blocks. Even at the lower rates of seeding the ground cover is more than enough for surface erosion protection. Therefore, the seeding rate for broadcasting could be below 11 kg/ha while drill seeding rates could be less than 6 kg/ha to produce sufficient ground vegetative cover.

- Drill seeding produced a better and more uniform vegetative cover than broadcast seeding.
- The survival of woody seedlings was generally very low due to the heavy ground vegetative cover. The herbaceous species depleted great amounts of soil moisture during the growing seasons, consequently the woody seedlings suffered the stress of drought with resulting low survival rates.

Strip-seeding Project

Low tree and shrub survival has been one of the major problems facing our reclamation programs. Standard reclamation procedures involve seeding of grasses and legumes on newly turned-over areas in an effort to avoid erosion and build up soil organic matter. Commonly, woody seedlings are planted in these areas after herbaceous vegetation has become well established. Competition for light, nutrients and especially moisture between herbaceous and woody species usually results in high mortality rates for the woody seedlings which cannot compete with the tremendous moisture uptake by grasses and legumes. Therefore, alteration of ground vegetation cover is desired in order to promote tree and shrub establishment.

The turnover of tailings dyke Cells 17 and 18 in 1982 provided an opportunity to study vegetation manipulation on an area of relatively flat tailings sand. Therefore the strip seeding project was designed and set up to evaluate woody plant survival on various herbaceous cover seeding patterns.

There were 12 plots, 40 x 80 m each in size, with the four seed treatments replicated three times, in a randomized design over the experimental area. The four seed treatments were: (1) No seeding (control); (2) 1-m strip seeding (1-m strip of grasses and legumes drill seeded with a 1-m strip unseeded); (3) 3-m strip seeding (1-m strip of grasses and legumes drill seeded with 3-m unseeded); and (4) Drill seeded (the entire plot drill seeded with grasses and legumes). Drill seeding was done at the end of May 1982 using the Rangeland drill.

Vegetation percent cover and biomass were assessed in August 1982. Not surprisingly, the percent cover assessment showed a large number of invading plant species, since the peat from the east muskeg storage pile used for top-soiling contains numerous weed seeds. Fireweed (Epilobium angustifolium), Canada bluegrass (Poa compressa), and stinging nettle (Urtica dioica) are the most common species found on the plots. Of the seeded species, slender wheatgrass and alfalfa appear to be the most abundant. Brome grass and timothy were seeded at very low rates resulting in low percent cover values.

Jack pine and green alder seedlings are to be planted in both the seeded and unseeded strips so that a direct comparison between survival and herbaceous cover can be made. One half of the area was planted in the fall on September 20 - 23, 1982. The other half will be planted in the spring (i.e. mid-May 1983). The split planting was designed to compare survival rates between spring and fall planting.

Legume Inoculation Project

This project was initiated to identify and develop ways of improving legume performance. Field testing of legumes inoculated with locally-isolated and commercial Rhizobium strains was established in 1981. Annual assessments have consisted mainly of the evaluation of legume performance by sampling biomass, species cover and alfalfa nodulation.

Biomass results for grass and alfalfa are listed in Table 1. Biomass of grass was correlated positively with amounts of nitrogen fertilizer applied. Alfalfa biomass showed the reverse trend, with higher nitrogen fertilizer rates resulting in lower alfalfa biomass. Mean biomass figures for inoculum treatments were variable for both grass and alfalfa production. The bare seed treatment resulted in the highest grass biomass with lower biomass for all other inoculum treatments. These differences, however, were not significant. The reverse trend is clearly demonstrated for alfalfa. The bare seed produced the lowest biomass while higher alfalfa biomass was produced with all other inoculum treatments although differences between the various inoculum treatments were not significant. Monitoring of alfalfa performance as affected by inoculum treatment is expected to continue for several years.

Results of the alfalfa nodule assessment did not clearly show the superiority of any treatment in terms of nodule numbers and nodule biomass although the locally-isolated (SYN) inoculant indicated a higher number of nodules that were generally larger and multilobed on the alfalfa roots. A more extensive evaluation of these treatments will be made in 1983.

REFORESTATION RESEARCH

Pre-planting Herbicide Project

In addition to other methods of vegetation manipulation, the use of herbicides to control herbaceous vegetation for the improvement of woody plant establishment is being investigated. The pre-planting herbicide project was initiated in 1982. The objective was to evaluate the effectiveness of 2 herbicides as tools for creating linear strips on revegetated tailings dyke.

The experiment was conducted on flat terrain at the north end of Syncrude's tailings dyke. The tailings sand was amended with 10 cm clay and 15 cm muskeg peat incorporated to approximately 30 cm with the aid of a heavy duty cultivator. The experimental plots were broadcast seeded with the following seed mixture at 34 kg/ha on June 9:

Table 1. Mean values¹ for grass and alfalfa biomass for the various treatments.

Treatment		Mean Grass biomass	Mean alfalfa biomass
Fertilizer rate	0 kg/ha	734.9	1967.7
	23 kg/ha	899.6	1671.1
	45 kg/ha	980.5	1218.2
	90 kg/ha	1111.8	1168.4
Inoculum treatment ²	B	1348.4	1085.0
	B+N	787.6	1710.8
	C-N	1035.4	1584.6
	C-A	816.0	1458.4
	C-S	779.4	1475.3
	C-N-R	916.0	1719.0
	C-S-R	839.1	1511.4

¹Mean values are calculated in kg/ha from raw data.

²B Bare seed
 BN Bare seed + Nitragen
 CN Coated Nitragen
 CA Coated Australia
 CS Coated Syncrude
 CNR Coated Nitragen-raked
 CSR Coated Syncrude-raked

40% Slender wheatgrass	<u>Agropyron trachycaulum</u>
25% Crested wheatgrass	<u>Agropyron cristatum</u>
2% Timothy	<u>Phleum pratense</u>
3% Russian wild rye	<u>Elymus junceus</u>
20% Alfalfa	<u>Medicago sativa</u>
10% Red clover	<u>Trifolium pratense</u>

To determine the best application time for the most effective vegetation control, two types of herbicides were used: pre-emergence and postemergence. Seven treatments were implemented with 3 replications for a total of 21 plots. The treatments were: a control where no herbicide was applied; Afolan-F as pre-emergence vegetative control applied at 5.0 and 10.0 l/ha on June 14 just prior to seed germination; Glyphosate as early post-emergence applied at 4.75 and 9.50 l/ha on August 15; and Glyphosate applied as late post-emergence at 4.75 and 9.50 l/ha on September 1. All the herbicides were applied, with a hand operated sprayer, in narrow strips 20 m long by 2 m wide.

Two weeks after the last herbicide application, jack pine and green alder seedlings were planted along the clear strips at 1-m spacing in alternate order.

Assessment of ground cover made in the fall 1982 showed no significant differences between treatments. The effects of ground cover removal on woody plant seedlings growth will be monitored for several years.

Stock Size Project

Successful establishment of woody plants on the tailings dyke depends on the type and condition of planting stock, planting quality and site and weather conditions at the time of and shortly after planting. A suitable planting stock size has not at this time been developed. In 1981, a demonstration trial was initiated to examine the relationship between all of the available seedling sizes at Syncrude's greenhouse and their outplanting performance on amended tailings sand. The test location was on Syncrude's Dyke Cell No. 25.

A total of 26 combinations of seedling species and sizes were planted on May 17 on a tailings dyke amended with 10 cm clay, 15 cm muskeg peat, 336 kg/ha of triple superphosphate (0-45-0) and 112 kg/ha of potassium chloride (0-0-60) incorporated to a depth of 30 cm. Sizes were differentiated by age class and the size and type of containers the seedlings were grown in. Individual species were planted in rows of 20 seedlings spaced at 1.5 m apart with 1.0 m between rows. The rows were randomly assigned within each of 3 replications. No other treatments were implemented.

The area was not seeded with either grasses or legumes as normally done on Syncrude's dyke. Although sparsely distributed, the first year vegetation was made up almost entirely of lamb's-quarters (Chenopodium album). In the second year there was a shift in vegetation type. The lamb's-quarters had completely disappeared and grasses and legumes were the dominant species. Assessments

showed that 66% of the experimental area remained vegetation free. No erosion was observed over the two year period. It is apparent from this trial that vegetation cover as low as 34% is sufficient to resist soil erosion on the Syncrude's dyke with a 4:1 slope.

Seedling survival for all species and sizes has been exceptionally high over the two seasons which could be attributed to good planting quality as well as the lack of competition for available soil moisture between woody and herbaceous vegetation. This is exemplified by the high rate of survival during the first season even though there was a prolonged summer drought soon after the seedlings were planted.

A summary of the mean percent survival for 1981 and 1982 and the mean height growth for 1982 are shown in Table 2. A slight decrease in survival from 97.1 to 92.8% was recorded in fall 1982. Mortality occurred mainly on the extremely "pot-bound" jack pine where new roots failed to egress out of the root plugs. Sand deposition, from the upper dyke lift, accounted for some of the missing small seedlings while shoot die-back was the main cause of the alder mortality.

Seedling growth at the end of the second season was excellent. Negative or insignificant growth increments were recorded on seedlings with the least amount of root egression. It is imperative that seedlings be outplanted before the roots entangle and suffocate themselves within the containers.

Planting Time Project

For the successful establishment of woody plant seedlings, the time of planting can be an important factor. There must be sufficient soil moisture available to the newly planted seedlings. Studies have shown that the root regeneration potential of forest tree seedlings fluctuates throughout the season. Optimum planting time, therefore occurs when the rate of root growth and soil moisture availability coincide. To determine this time span for the Athabasca tar sands area, a planting time trial was initiated in 1982 to be continued for 5 consecutive years (1982 - 1986) from April to October to take into account seasonal precipitation fluctuations.

The experiment was conducted on level tailings sand amended and incorporated with 10 cm clay and 15 cm muskeg peat. All the subsequent trials will be implemented on similar soil in the vicinity of the first one.

In 1982, the species planted were:

White spruce	<u>Picea glauca</u>
Jack pine	<u>Pinus banksiana</u>
Trembling aspen	<u>Populus tremuloides</u>
Green alder	<u>Alnus crispa</u>
Saskatoon	<u>Amelanchier alnifolia</u>
Caragana	<u>Caragana arborescens</u>
Dogwood	<u>Cornus stolonifera</u>
Buffaloberry	<u>Shepherdia canadensis</u>

Table 2. Mean percent survival and growth of the various stock sizes after two growing seasons.

SPECIES	AGE CLASS		MEAN % SURVIVAL			MEAN ANNUAL HEIGHT GROWTH (cm)
	REARING PERIOD	CONTAINER SIZE & TYPE	1981 FALL	1982 SPRING	1982 FALL	
Aspen	June 1980 - May 1981	SB (7)	97	97	97	8.8
J. pine	June 1979 - May 1981	SL (T)	100	100	100	-2.9
J. pine	June 1979 - May 1981	SB (20)	100	100	77	1.4
J. pine	Feb. 1980 - May 1981	SL (5)	100	100	100	7.7
J. pine	Feb. 1980 - May 1981	SL (H)	100	100	97	12.5
J. pine	Feb. 1980 - May 1981	SL (T)	100	100	100	10.8
J. pine	Feb. 1980 - May 1981	SB (8)	100	100	100	9.2
J. pine	Feb. 1980 - May 1981	SB (20)	100	100	100	4.1
Larch	June 1979 - May 1981	SB (8)	100	100	87	4.8
W. spruce	June 1979 - May 1981	SL (H)	100	96	93	2.3
W. spruce	June 1979 - May 1981	SB (8)	100	100	100	3.1
W. spruce	Feb. 1980 - May 1981	SL (5)	100	100	100	9.1
W. spruce	Feb. 1980 - May 1981	SL (H)	100	100	97	4.3
W. spruce	Feb. 1980 - May 1981	SB (8)	93	90	86	6.1
W. spruce	June 1980 - May 1981	SL (5)	80	74	74	5.4
W. spruce	June 1980 - May 1981	SL (H)	100	100	100	11.7
B. berry	June 1980 - May 1981	SL (5)	100	100	100	7.2
B. berry	Feb. 1981 - May 1981	SL (H)	90	90	88	12.1
Caragana	June 1980 - May 1981	SL (5)	93	90	83	6.2
Caragana	June 1980 - May 1981	SL (H)	100	100	90	8.4
Dogwood	June 1980 - May 1981	SL (5)	100	100	97	5.6
Dogwood	June 1980 - May 1981	SL (H)	100	100	100	9.6
G. alder	June 1980 - May 1981	SL (5)	97	97	79	5.6
G. alder	June 1980 - May 1981	SL (H)	100	100	85	6.5
Saskatoon	June 1980 - May 1981	SL (5)	97	95	95	10.1
Saskatoon	June 1980 - May 1981	SL (H)	97	97	90	6.9

SL = Spencer Lemaire
(H) = Hillsons
(T) = Tinus

SB = Styroblock

Plantings were carried out at two-week intervals. At each planting, five seedlings of each species were planted in a row in 3 replications for a total of 15 seedlings per species per planting time. The rows were randomly assigned within each of the subplots. Two weeks after planting and every two weeks thereafter the seedlings were assessed for survival. Available soil moisture was determined at each planting time using the gravimetric method.

A summary of seedling survival and soil moisture availability at each planting time are shown in Table 3. In 1982, soil moisture was relatively high throughout the season except for two low points recorded on June 23 and September 23. These short drought periods had no detrimental effect on the seedling survival rate. Survival was excellent for all species. This could be attributed to ample soil moisture present at the time of planting, good planting quality and the lack of competition from ground vegetation.

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Table 3. Summary of % seedling survival and percent soil moisture at various planting times - 1982.

<u>SPECIES</u>	<u>June 7</u>	<u>June 23</u>	<u>July 5</u>	<u>July 19</u>	<u>Aug. 3</u>	<u>Aug. 19</u>	<u>Aug. 31</u>	<u>Sept. 13</u>	<u>Sept. 23</u>	<u>Oct. 12</u>
Jack pine	100	100	100	100	100	100	100	100	100	100
White spruce	100	100	100	100	100	100	100	100	100	100
T. aspen	100	100	100	100	100	100	100	100	100	100
Green alder	100	87	93	100	100	100	100	100	100	100
Saskatoon	100	100	100	100	100	100	100	100	100	100
Dogwood	100	100	100	100	100	100	100	100	100	100
Buffaloberry	93	93	93	93	93	100	100	100	100	100
Caragana	93	100	100	100	100	100	100	100	100	100
MEAN	98.2	97.5	98.2	99.1	99.1	100	100	100	100	100
% Soil Moisture (0-25 cm)	42.5	17.7	39.4	41.5	38.7	39.4	33.6	35.4	12.0	28.1

PLANT GROWTH AND MYCORRHIZAL POTENTIAL OF OVERBURDENS TO BE CONSIDERED
FOR USE IN THE RECLAMATION OF EXTRACTED OIL SANDS

R.M. Danielson, S. Visser, and D. Parkinson¹

ABSTRACT

Two shallow mineral overburdens, a deep mineral overburden and a peat overburden from northern Alberta were examined to determine effects of each on the growth of jack pine and slender wheatgrass. Plants were grown in the greenhouse in 30 cm deep cores in which the overburdens were placed in either 5 or 15 cm deep layers over oil sand tailings. For comparison with current reclamation practices, cores containing a mixture of sand, peat and deep overburden were also used.

The growth of slender wheatgrass was best in the peat and very poor in the deep overburden. Jack pine also grew very poorly in the deep overburden but reasonably well in the other three overburdens. There was extensive root development of both species in the sand layer beneath all four overburden types. Increasing the depth of peat from 5 to 15 cm resulted in a decrease in the growth of both plants whereas increasing the depth of the mineral overburdens had favorable effects. The amount of available P was much higher in sand under the 5 cm layers than sand under the 15 cm layers. Iron and Mn uptake was suppressed with the thick layer of peat. Mixing 15 cm of peat with deep overburden and sand did not affect the growth of slender wheatgrass but reduced shoot production of jack pine.

Both ecto- and vesicular-arbuscular (VA) mycorrhizal inoculum was present in all four overburdens. VA development was very low in peat whereas plants in the shallow overburdens became heavily mycorrhizal. Infection did not spread from the overburden layer to roots in the tailing sand. Jack pine roots in the peat and two shallow overburdens were heavily infected after 4 months.

¹Dept. of Biology, The University of Calgary, Calgary, Alberta T2N 1N4. Full details of this work will appear in a forthcoming issue of the Canadian Journal of Soil Science.

TESTING OF SEED PRE-GERMINATION

TREATMENTS FOR FOUR ROSACEAE

NATIVE TO ALBERTA

By

P. King,¹ G. Grainger² and A. Straka²

ABSTRACT

The paper deals with the preliminary seed pre-germination treatment testing for Rosa acicularis, Rosa woodsii, Rubus parviflorus and Rubus strigosus: four shrub species having potential for reclamation in the Eastern Slopes of Alberta. A summary of the literature, experimental results and discussion are presented.

1. GENERAL INTRODUCTION

In the foothills and Rocky Mountain Eastern Slopes of Alberta, renewable resources such as water, recreation, wildlife production and timber production are of critical importance. However, they must be managed simultaneously with non-renewable land uses such as coal mining, oil and gas activities, gravel extraction and other industrial land disturbances. Because of the continuing yield from renewable resources, Alberta non-renewable resource development policy requires restoration to pre-disturbance land status.

Traditionally, reclamation has been carried out using agronomic grasses and legumes. The use of native woody plants having value for erosion control, watershed protection, production of browse and cover for wildlife, site amelioration, esthetics or timber production has potential in returning disturbed sites to greater biological and economic value.

¹ Reforestation and Reclamation Branch, Alberta Forest Service, Alberta Energy and Natural Resources, Edmonton, Alberta.

² Alberta Tree Nursery and Horticulture Center, Alberta Agriculture, Oliver, Alberta.

The Alberta Forest Service, the Alberta Tree Nursery and Horticulture Center and the Reclamation Research Technical Advisory Committee are conducting a program to evaluate and select native woody species for use in reclamation in the area. The ultimate operational use of any plant species in part depends upon the feasibility of large-scale propagation. Previous work reviewed the seed pre-germination treatments required by 25 candidate species (King 1980). Subsequently, the needs of those species were further appraised and a seed-testing research project designed for those woody plants identified as difficult to grow from seed (King 1981). The four shrubby members of the Rosaceae reported here are listed in Table 1. Another report containing the detailed results and discussion on all of the shrub species investigated in this phase of the project will be available shortly (King, Grainger and Straka, in press).

Table 1

FOUR NATIVE ROSACEOUS SHRUBS INVESTIGATED
IN SEED PRE-GERMINATION
TREATMENT TESTING (PRELIMINARY PHASE)¹

Scientific Name	Common Name(s)
<u>Rosa acicularis</u> Lindl.	prickly rose
<u>Rosa woodsii</u> Lindl.	Fendler woods rose, common wild rose, wood rose
<u>Rubus parviflorus</u> Nutt.	thimbleberry
<u>Rubus strigosus</u> Michx.	wild red raspberry, red raspberry

¹ Nomenclature follows that of Moss 1959.

2. ROSA ACICULARIS SEED PRE-GERMINATION TREATMENT TEST

2.1 Introduction

Rosa acicularis Lindl. (prickly rose) in Alberta is a common, deciduous shrub which is 0.5 - 2.5 m in height (Moss 1959). It is prevalently a species of the boreal zone (Densmore and Zasada 1977) but also occurs in the prairie, foothills and montane regions (Campbell et al. 1966; Taylor 1973). Prickly rose, highly adapted to disturbance (Plummer 1976; Russell 1979), is a promising species for reclamation.

The fruit of the rose is an achene, several to many of which are borne within a fleshy, berrylike hip (Gill and Pogge 1974). The rose "seed" consists of an embryo enclosed within a thin testa and surrounded by a thick sutured pericarp (Densmore and Zasada 1977). This is referred to hereafter as the seed.

2.2 Literature Review

The literature on the propagation of the species from seed is summarized in Table 2. It is neither extensive nor conclusive, while the work of Densmore (1974) and Densmore and Zasada (1977) forms the basis of authoritative information. It would appear that dormancy is caused by some property of the seed coat other than impermeability as well as by the physiological condition of the embryo. A sequential warm and cold stratification may be a promising pre-germination treatment for R. acicularis.

The role of hip and seed ripeness in the dormancy of Rosa is not well documented in the literature. Hartmann and Kester (1968) recommended that rose hips be collected as soon as they are ripe and still firm but did not cite any documentation to support such a recommendation. The role of germination inhibitors and promoters in seed dormancy has been studied in Rosa rugosa (Svejda and Poapst 1972) and in other members of the Rosaceae (Pollock and Olney 1959; Lin and Boe 1972). These studies dealt only with the relative changes in the concentrations of these substances during after-ripening but found that germination was dependent upon the levels of the inhibitors decreasing while the promoters remained constant or

Table 2
SUMMARY OF REVIEW ON SEED PRE-GERMINATION
TREATMENTS FOR ROSA ACICULARIS

Reference	Seed Pre-germination Treatment	% Germ. Obtained	Location	Researcher's Comments
USDA 1979	48-hour soak in gibberellin solution (3.46 g/1000 cc, Rootone F/distilled water), followed by warm stratification at 71°F (21.7°C) for 60 days, followed by cold stratification at 41°F (5°C) for 90 days	not reported	none given	
Babb 1959	sulphuric acid soak for 1-2 hours, followed by cold stratification at 41°F (5°C) for 75 days	not reported	Alaska	
Dehleyer et al. undated.	cold stratification at 0-5°C for 5 months	not reported	Alberta	
Densmore 1974; Densmore and Zasada 1977	warm stratification at 25°C for 118 days, followed by cold stratification at 5°C for 3 months cold stratification at 5°C for 360 days sulphuric acid scarification for 1 hour sulphuric acid scarification for 1 hour, followed by cold stratification at 5°C for 360 days	90+ 55 4 60	Alaska Alaska Alaska Alaska	subsidiary studies found that: (a) the pericarp and testa were not impermeable and acid scarification was not a beneficial pre-germination treatment (b) the major causes of seed dormancy were the presence of the testa and the physiological condition of the embryo
Heit 1967a				the genus Rosa does not generally have impermeable seed coats and scarification is not a beneficial treatment

increased. In some roses the level of inhibitors in the hip, seed coverings and embryo is related to the stage of hip and seed development (Hartmann and Kester 1968). In R. canina the effect of inhibitors in ripe hip tissue is so pronounced that achenes left in the hips remain dormant in response to dual warm and cold stratification which produces substantial germination in free achenes (Rowley 1956). Therefore, it was hypothesized that hip and seed ripeness at the time of collection and extraction may play an important role in the germinability of R. acicularis seed.

2.3 Methods and Materials

A factorial experiment was designed with four replicates and, as factors, ripeness phase ("not fully ripe" in which the hips were a yellowish-orange color and very firm in texture, or "fully ripe" in which the hips were a deep red color and firm in texture), warm stratification (in acid peat moss at 25°C for 0, 60, 90 or 120 days) and cold stratification (in acid peat moss at 5°C for 0, 60, 90 or 120 days). The seed used in the test was collected August 16, 1980 at latitude 53°22' N, longitude 117°45' and an elevation of 1 250 m. After extraction and cleaning, the seed was dried to 6.0 - 6.2 percent moisture content and then stored in sealed containers at 0°C until the experiment commenced. The germination testing conditions used were: a constant 20°C temperature, 16 hours of light per day, a vermiculite substrate in closed petri dishes and an 84-day test duration (with germination counts made every seven days).

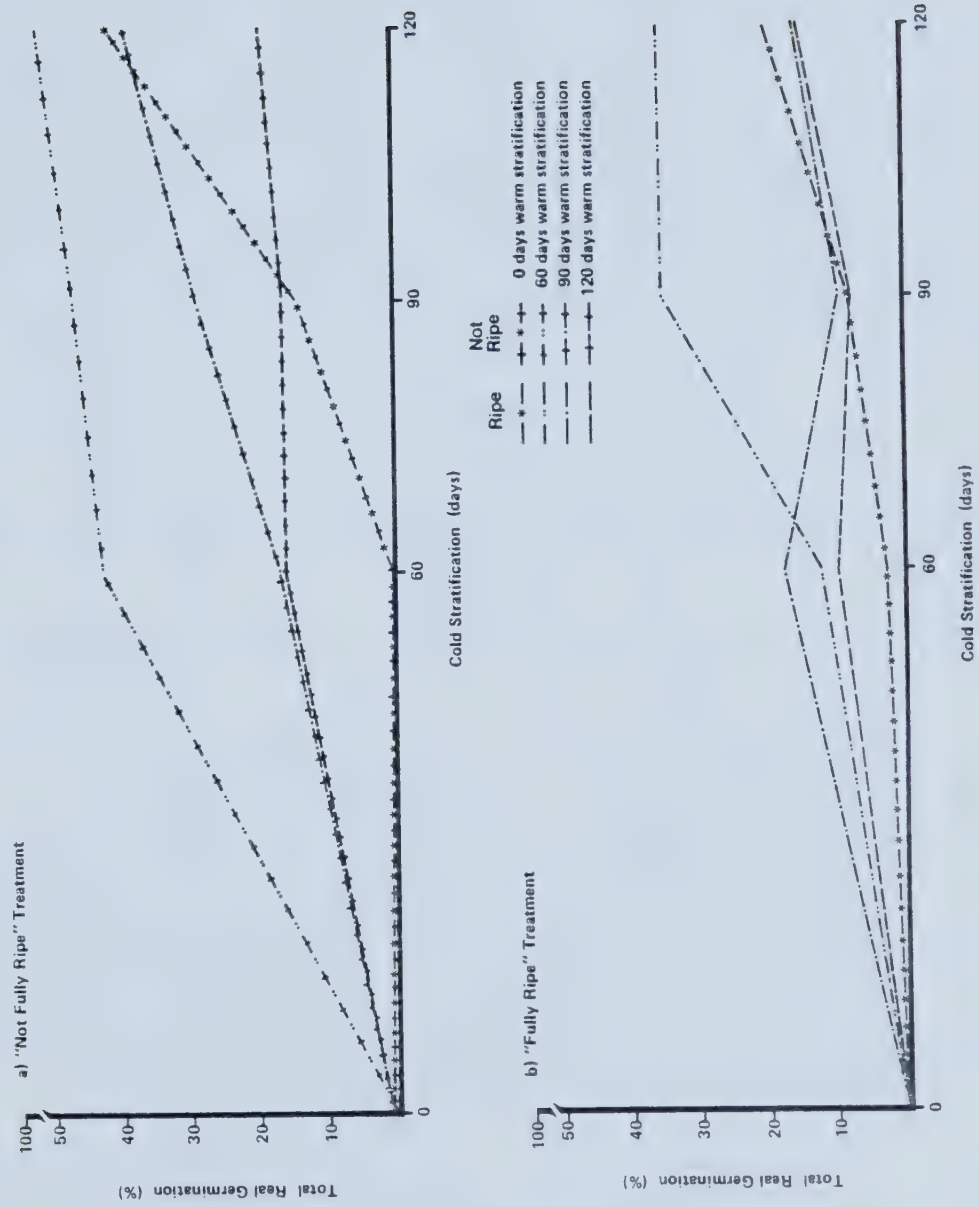
A seed considered as germinated in this experiment met the criteria for normal shrub seedlings of the Association of Official Seed Analysts (1978). All results are reported as real germination.

2.4 Results and Discussion

The total germination results obtained in the experiment are presented in Figure 1.

Germination in unstratified seed was not appreciable. Cold stratification alone gave relatively incomplete germination, although total germination was generally proportional to the duration of the cold stratification treatment.

FIGURE 1. TOTAL GERMINATION IN *ROSA ACICULARIS* SEED



The maximum levels of germination across ripeness treatments were obtained in response to 60 days of warm stratification followed by 120 days of cold stratification. The use of longer periods of warm stratification suppressed germination levels commensurately with the duration of warm stratification. This is markedly different from the results obtained by Densmore (1974) and Densmore and Zasada (1977) who obtained maximum germination after 118 days of warm stratification (followed by cold stratification). The warm, moist conditions of warm stratification enhance bacterial and fungal activity (Giersbach 1937; Nikolaeva 1969; Pellett 1973) and, therefore, the decrease in germination in this experiment with the 90 and 120 days of warm stratification treatments may be attributed to microbial damage of the embryo. The results suggest a role which warm stratification may have played in the lot tested was that of chemical breakdown in a dormancy-causing exterior seed layer (possibly the testa). Svejda and Poapst (1972) documented the presence of such inhibitors in R. rugosa. Warm stratification may also be required in part to overcome physiological embryonic dormancy as discussed in the Alaskan studies.

The magnitude of some of the germination levels was not large when compared with those obtained by Densmore (1974) and Densmore and Zasada (1977). It is possibly that this may be partially attributed to the annual variability in seed germinability. In collections from the Banff area, it was noted the germination obtained from the 1980 seed crop was lower than in other years (T. Laidlaw, personal communication). It has been demonstrated that climatic variability affects the relative germinability of cold-stratified hybrid rose seed (Von Abrams and Hand 1956).

The ripeness treatment effects were significant in this experiment. The seed from the "not fully ripe" collection yielded greater germination than did the "fully ripe" treatment. This result suggests that hip ripeness at the time of collection and extraction affects the germinability of R. acicularis seed. Since many previous seed collections have been carried out in September or October (Dick 1979; Fedkenheuer and Heacock 1980; King, unpublished), the results may indicate that collections could be carried out earlier than has been traditional.

3. ROSA WOODSII SEED PRE-GERMINATION TREATMENT TEST

3.1 Introduction

Rosa woodsii Lindl. (woods rose, Fendler woods rose, common wild rose) is a tall, deciduous shrub of 0.3 - 2.0 m in height (Moss 1959). Prevalently a species of bluffs, dry slopes, and sand hills in the prairies but also common on riverbanks and forest clearings in the boreal and subalpine regions (Watson et al. 1980), it is commonly associated with disturbance (Russell 1979) and has potential in reclamation of mined lands and soil stabilization (USDA, undated).

The fruit of the rose is an achene, several to many of which are borne within a fleshy, berrylike hip (Gill and Pogge 1974). The rose "seed" consists of an embryo enclosed within a thin testa and surrounded by a thick sutured pericarp (Densmore and Zasada 1977). This is referred to hereafter as the seed.

3.2 Literature Review

The published information on seed propagation is summarized in Table 3. The literature is inconclusive on both the dormancy mechanisms of the species and the treatments required to break dormancy. Only one reference presented germination yield data: 40 - 60 percent germination resulted from a dual stratification treatment. This reported need for warm stratification followed by cold stratification agreed with the recommendations of Gill and Pogge (1974) and Dick (1979). Various other sources advised a simple cold stratification treatment at temperatures ranging from 0° to 10°C for periods as long as one year (Chadwick 1935; Swingle 1939; DenHeyer et al., undated). Stark (1966) recommended a dual treatment of concentrated sulphuric acid followed by cold stratification, although Heit (1967a) stated it is doubtful that seed of the genus Rosa would benefit from scarification.

Table 3
SUMMARY OF REVIEW ON SEED PRE-GERMINATION
TREATMENTS FOR ROSA WOODSII

Reference	Seed Pre-germination Treatment	% Germ. Obtained	Location	Researcher's Comments
USDA 1979	warm stratification at room temperature for 60 days, followed by cold stratification at 41°F (5°C) for 90 days (two seed lots)	40, 60	Idaho	
Chadwick 1935	cold stratification at 41°F (5°C) for 300 days (in moist peat)	not reported	none given	
DeHeyer et al. undated.	cold stratification at 0-5°C for 5 months	not reported	Alberta	
Dick 1979	Warm stratification at 20-27°C, varying temperatures for 60-90 days, followed by cold stratification at 2-5°C for 90-120 days	not reported	British Columbia	
Gill and Pogge 1974	recommended warm stratification preceding cold treatment (no further details given)	not reported	none given	
Heit 1967a				it is doubtful that that Rosa spp. will benefit from treatment for hard seed
Stark 1966	sulphuric acid scarification followed by cold stratification at 41°F (5°C)	not reported	Nevada	
Swingle 1939	cold stratification at 32-50°F (0-10°C) for 300 days	not reported	none given	

3.3. Methods and Materials

R. woodsii hips were collected September 15, 1980 at latitude 53°55' N, longitude 119°15' and an elevation of 1 320 m. After extraction and cleaning, the seed was dried to 6.0 percent moisture content and then stored in sealed containers at 0°C until the experiment commenced. The description of the experimental design, the treatments and the germination testing regime and methods were as given previously for R. acicularis.

3.4 Results and Discussion

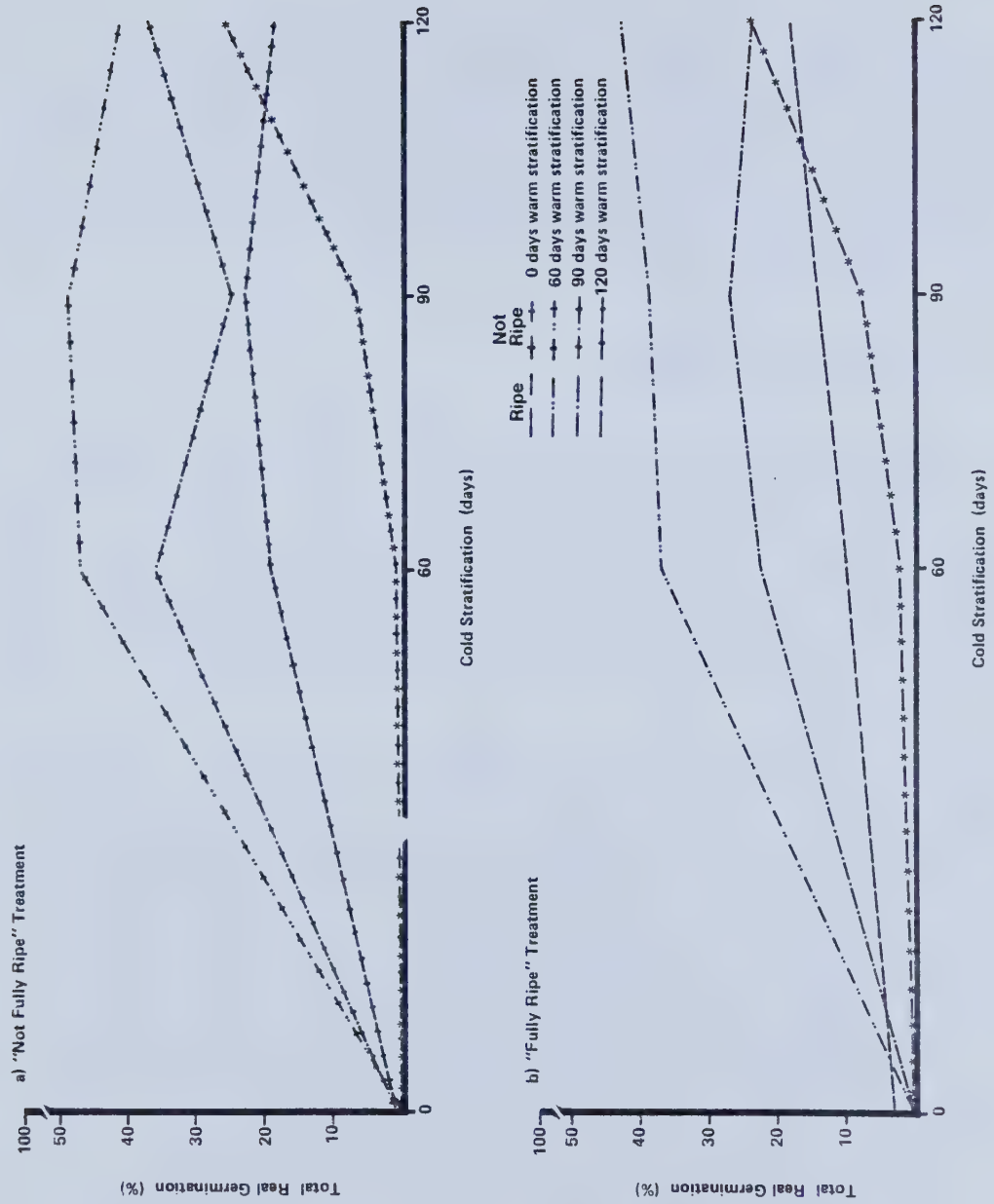
The total germination results obtained in this experiment are presented in Figure 2.

Seeds which were untreated with warm or cold stratification did not germinate. The use of warm stratification alone did not yield appreciable levels of germination. Simple cold stratification treatments gave relatively incomplete seed germination, although it was generally proportional to the duration of the cold stratification.

The maximum levels of germination across ripeness treatments were obtained in response to 60 days of warm stratification followed by 90 or 120 days of cold stratification. Both the duration of this dual pre-germination treatment and the level of germination obtained generally agree with that reported by the Native Shrub Production Project in the western United States (USDA 1979). In the experiment herein, the use of warm stratification for periods exceeding 60 days suppressed germination levels commensurably with the duration of the stratification. A similar trend was observed in R. acicularis and, as discussed under that species, the decrease in germination with the longer warm stratification periods may be due to microbial damage of the embryo.

The ripeness treatment effects were significant at the 95 percent level in the experiment. The seeds from the "not fully ripe" treatment generally yielded greater germination than did the "fully ripe". As discussed under R. acicularis, this may have practical as well as biological benefit.

FIGURE 2. TOTAL GERMINATION IN ROSA WOODSII SEED



4. RUBUS PARVIFLORUS
SEED PRE-GERMINATION
TREATMENT TEST

4.1 Introduction

Rubus parviflorus Nutt. (thimbleberry) is an erect shrub, 0.5 - 2.0 m tall (Moss 1959), common in forest margins and openings in the Rocky Mountains of southwestern Alberta and rarer in the more northerly Rockies of the province (Looman and Best 1979). Occurrence was common on disturbed sites in the southern Rocky Mountain Eastern Slopes of Alberta (Russell 1979).

The fruit of Rubus is an aggregate of small succulent drupes, each of which contains a single hard-pitted nutlet (Brinkman 1974). The nutlets are referred to hereafter as seeds. The date of R. parviflorus fruit ripening is highly variable, occurring as early as June 30 until September 3 in northern Idaho (Schmidt and Lotan 1980).

4.2 Literature Review

The only reference found on thimbleberry seed pre-germination treatments reported "good" levels of germination in response to both 50 minutes of acid scarification and cold stratification at 2°C for 6 months (Marchant 1980).

4.3 Methods and Materials

A factorial experiment was designed with four replicates and, as factors, scarification (seeds were non-scarified or mechanically scarified), warm stratification (in acid peat moss at 25°C for 30, 60, 90 or 120 days) and cold stratification (in acid peat moss at 5°C for 60, 90 or 120 days).¹ At the time of the seed test unstratified replicates were also tested but not included in any analyses. The seed used in the foregoing was collected from ripe fruit August 28, 1980 at latitude 49°30'N, longitude 114°20' and an elevation of 1 835 m. After extraction and cleaning, the seed was dried to 6.0 percent moisture content and stored in sealed containers at 0°C until the experiment commenced. The germination testing

¹ The order of treatment application followed the sequence stated.

conditions used were: an alternating temperature of 20/30°C in a 16/8-hour cycle, eight hours of light per day (during the high temperature period), a quartz sand substratum in closed petri dishes and a 35-day test duration (with germination counts being made every seven days).

A seed considered as germinated in this experiment met the criteria for normal shrub seedlings of the Association of Official Seed Analysts (1978). All results are reported as real germination.

4.4 Results and Discussion

The total seed germination results obtained in this experiment are presented in Figure 3.

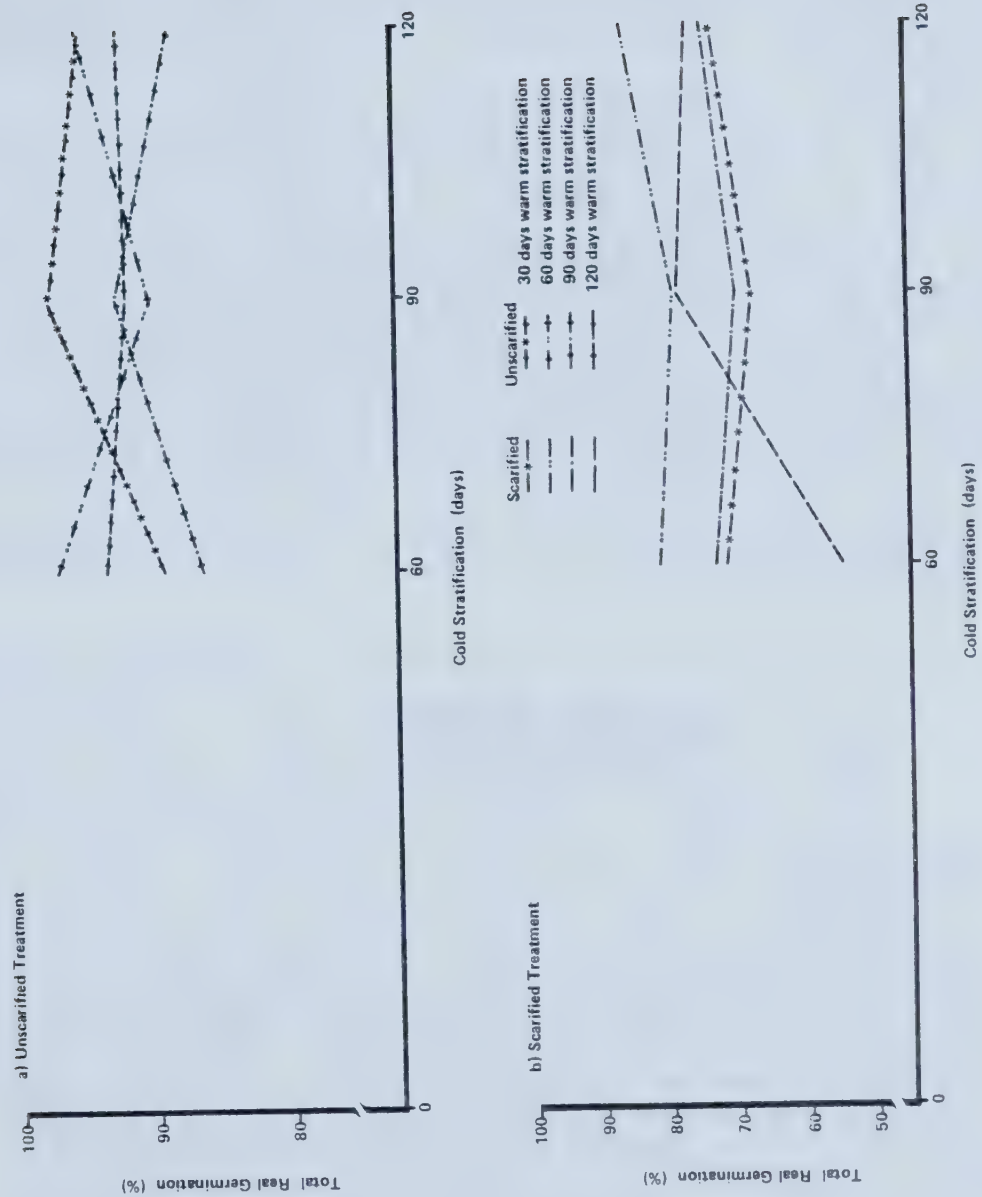
Seeds which were not warm or cold-stratified germinated relatively incompletely (Table 4). In the experiment maximum germination was obtained in response to 30 or 60 days of warm stratification followed by 90 or 60 days respectively of cold stratification in unscarified seed.

It should be noted that the cold stratification effect was not significant in the analysis and that, therefore, germination was independent of the duration of the cold stratification treatments used. However, the differences in germination between the unstratified samples and the experimental results suggest that cold stratification was likely a necessary pre-germination treatment (although this experiment did not establish a minimum cold requirement).

Table 4
GERMINATION IN UNSTRATIFIED
RUBUS PARVIFLORUS SAMPLES

Mechanical Scarification	Duration of Warm Stratification (Days)	Duration of Cold Stratification (Days)	Total Real Germination (%)
no	0	0	29
yes	0	0	16

FIGURE 3. TOTAL GERMINATION IN *RUBUS PARVIFLORUS* SEEDS



Pre-germination treatment by mechanical scarification yielded less germination than was obtained in unscarified treatments. Scarification was not a beneficial treatment in this experiment. This result, the difference in germination between the non-scarified and scarified unstratified samples and the result of Marchant (1980) indicate that the physical structure of the seed coverings was not a major, if any, cause of dormancy.

The effect of warm stratification was significant in the experiment. Greater germination was obtained in response to 30 or 60 days of warm treatment while the levels were generally suppressed by the longer periods, likely because of microbial damage to the embryo. In the literature reviewed, warm stratification has been considered as playing various possible roles such as overcoming morphological dormancy (Heit 1971); physically breaking down hard seed coverings (Giersbach 1937; Pellett 1973; Krugman et al. 1974); chemically breaking down germination inhibitors in seed coverings (Densmore 1974), or initiation of requisite germination metabolic processes (Nikolaeva 1969; Villiers 1972). In the R. parviflorus lot tested it is doubtful that the first two functions were of great consequences, while either or both of the last two roles may have been of importance.

5. RUBUS STRIGOSUS SEED PRE-GERMINATION TREATMENT TEST

5.1 Introduction

Rubus strigosus Michx. (wild red raspberry) is a deciduous, bushy shrub, 0.6 - 2.0 m in height (Moss 1959). It is common on land disturbances throughout the latitudinal range of the Eastern Slopes of the Rocky Mountains and extends from the lower foothills and montane zones into the subalpine (Russell 1979). Also common throughout the boreal forest in clearings, at edges of woods and on burned areas (Watson et al. 1980), the species is a promising shrub for use in reclamation and erosion control.

The fruit of R. strigosus is an aggregate of small succulent drupes, each of which contains a single hard-pitted nutlet (Brinkman 1974). The nutlets are referred to hereafter as seeds.

5.2 Literature Review

The literature on the propagation of the wild red raspberry from seed is summarized in Table 5. It was inconsistent on the cause of and pre-germination treatment required to overcome dormancy.

5.3 Methods and Materials

Mature *R. strigosus* fruit was collected August 24, 1980 at latitude 52°50' N, longitude 116°55' and an elevation of 1 430 m. After extraction and cleaning, the seed was dried to 6.0 percent moisture content and stored in sealed containers until the experiment commenced. The description of experimental design, the treatments and the germination testing regime and methods were as given previously for *R. parviflorus*.

5.4 Results and Discussion

The total germination results obtained in this experiment are presented in Figure 4.

The germination of unscarified red raspberry seed was significantly greater than in scarified treatments. This result suggests that scarification is not required at least when warm stratification is also used as a pre-germination treatment. In the unstratified samples the difference in germination between unscarified and scarified seeds (Table 6) indicates that this seed lot may not have been hardseeded, which agrees with the findings of Afanasiev (1964), Copeland (1976) and Rose (1919). If there is seed-coat dormancy in *R. strigosus*, it is likely caused by some factor other than impermeability.

FIGURE 4. TOTAL GERMINATION IN *RUBUS STRIGOSUS* SEEDS

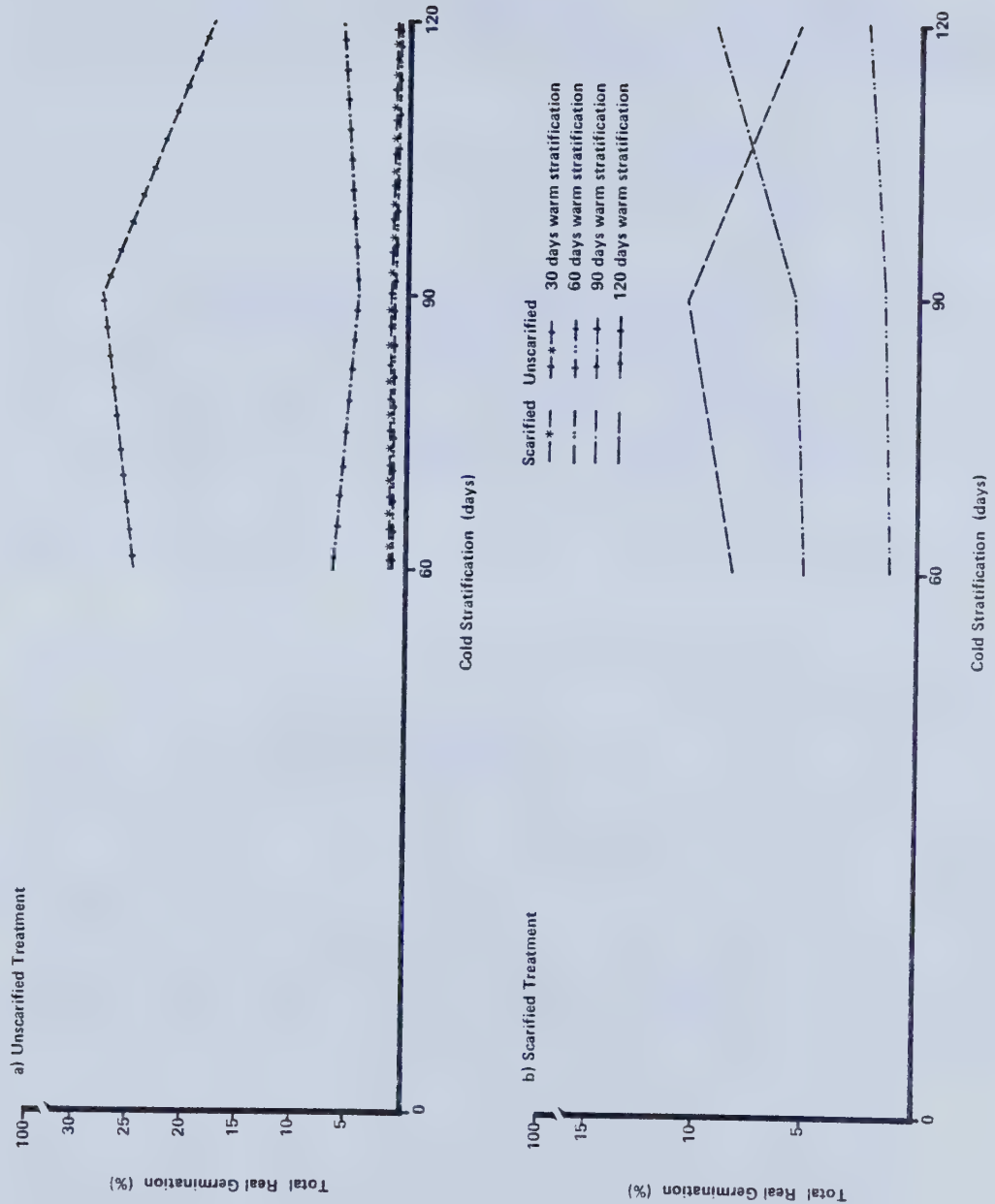


Table 5 -187-
SUMMARY OF REVIEW ON SEED PRE-GERMINATION
TREATMENTS FOR RUBUS STRIGOSUS

Reference	Seed Pre-germination Treatment	% Germ. Obtained	Location	Researcher's Comments
Afanasiev 1964				members of the genus do not have impermeable seed coats and do not require scarification; however, use of sulphuric acid scarification may accelerate other pre-germination treatments and germination
Babb 1959	sulphuric acid scarification for 1-2 hours, followed by warm stratification at 68-86°F (20-30°C) for 90 days, followed by cold stratification at 41°F (5°C) for 90 days	not reported	none given	
Brinkman 1974	sulphuric acid scarification for 20-60 minutes or a 7-day soak in sodium hypochlorite, followed by cold stratification at 36-41°F (2.2-5°C) for 120 days (six samples)	87	none given	
Chadwick 1935	sulphuric acid for 2 hours	not reported	none given	
Copeland 1976				seed coat is completely permeable to both water and gases but its mechanical resistance to the enlarging embryo prevents germination
Heit 1967a; Heit 1967b	sulphuric acid scarification for 10-30 minutes, followed by cold stratification at 34-38°F (1.1-3.3°C) for 1-3 months	not reported	none given	also reported that: a) species is hardseeded and requires scarification b) a warm-and-cold sequential stratification will give satisfactory germination
Rose 1919	sulphuric acid scarification for 2 hours (11 samples)	55-96	Illinois	testing was carried out on species' cultivars; study also found that: a) failure to absorb water does not limit germination as entire seeds were fully imbibed after 5 hours of water soaking b) dormancy is entirely associated with the endocarp and/or testa since germination of excised embryos was rapid and complete without the application of any additional treatments; hypothesized that seed-coat dormancy was due to mechanical resistance to embryonic enlargement
Scott and Ink 1957	sulphuric acid scarification for 20 minutes followed by warm stratification at room temperature for 2 months, followed by cold stratification at 34°F (1.1°C) for 3 months	54	none given	testing was carried out on species' cultivars; in the test the germination rate was low; the reported levels of germination were obtained over a four-month testing period; warm stratification played a significant role in germination in the test

Table 6
GERMINATION IN UNSTRATIFIED
RUBUS STRIGOSUS SAMPLES

Mechanical Scarification	Duration of Warm Stratification (Days)	Duration of Cold Stratification (Days)	Total Real Germination (%)
no	0	0	18
yes	0	0	1

The experimental results do not permit any conclusion to be made on the possibility of the seed coverings causing dormancy through mechanical restriction to embryonic enlargement as hypothesized by Rose (1919) and subsequently cited by others in the literature (Adams 1927; Copeland 1976). However, when carrying out seed-cutting tests it was noted that the endocarp and testa presented little resistance to cutting, even in unimbibed seeds.

This experiment and that of Scott and Ink (1957) both found that warm stratification had a significant effect on germination. The results of these two studies indicated that at least two to four months of warm stratification would be required to attain moderate levels of germination. Brinkman (1974) recommended a minimum of 90 days of warm stratification.

Germination was independent of the duration of the cold stratification treatment employed in the experiment. A comparison between the germination results obtained in the unstratified samples and the experimental treatments implies that cold stratification was generally of little benefit or detrimental. As previous research had also demonstrated that red raspberry embryos were non-dormant (Rose 1919), it may be inferred that cold stratification is not a necessary pre-germination treatment.

6. SUMMARY AND FUTURE RESEARCH

6.1 Rosa acicularis

The experimental results demonstrated that prickly rose hip ripeness at the time of seed collection had an effect on relative

seed germinability and indicated that there may be biological benefit from collecting hips before they have fully ripened. However, it should be noted that the stage of seed maturity is a critical consideration in making early collections and that this study did not examine this aspect.

The species requires stratification to obtain appreciable levels of seed germination. A simple cold stratification does not appear to be an adequate seed pre-germination treatment. Maximum germination was obtained in response to 60 days of warm stratification followed by 120 days of cold stratification, although a total treatment time of 180 days is pragmatically considered to be quite long.

Immediate further research will concentrate on the effects of the time of seed collection on seed germinability and other pre-germination treatments which may further increase germination levels and/or shorten stratification times. In the longer term, research may deal with the effects of climatic variability upon seed germinability, the effects of origin on germination or examination of the physiological role of warm stratification.

6.2 Rosa woodsii

The germination responses in Fendler woods rose were similar to those in R. acicularis. The maximum level of germination in this experiment was obtained in "not fully ripe" seed in response to 60 days of warm stratification followed by 90 days of cold stratification.

In the near future no further research is planned on R. woodsii. Efforts will be concentrated on R. acicularis.

6.3 Rubus parviflorus

In the experimental lot there was no benefit from scarification and it does not appear that hard seed was a cause of dormancy. Germination was independent of the cold-stratification treatments used in the trial, although it did appear that an undefined minimum duration of cold stratification was necessary in the species. Warm stratification for 30 to 60 days followed by cold stratification resulted in maximum germination. The physiological role of warm stratification was not known, although it may have been associated with chemical breakdown in the seed coverings or initiation of metabolic processes requisite to germination.

At this point, no further research on Rubus parviflorus is planned.

6.4 Rubus strigosus

Scarification did not benefit germination in the experiment. Cold stratification was of little benefit or detrimental to germination and may not have been a necessary pre-germination treatment, suggesting that the embryo was non-dormant. Warm stratification had a significant effect on germination, suggesting that dormancy was associated with the properties of the testa and/or endocarp. A minimum of two to four months of warm treatment would be necessary for the species.

Future research will examine the roles of the embryo and seed coverings in dormancy and pre-germination treatments which may enhance both total germination and germination rate.

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AN INTEGRATED APPROACH TO LAND INVENTORY
AND CAPABILITY ASSESSMENT

by

L. Knapik⁽¹⁾, D. A. Westworth⁽²⁾, A. W. Fedkenheuer⁽³⁾
and S. E. Stephansson⁽⁴⁾

ABSTRACT

An integrated approach was applied to an ecological resource inventory and land capability assessment of an area in northeastern Alberta. Interdisciplinary teams conducted intensive sampling of soils, vegetation and wildlife to classify and delineate functional ecosystem units. Environmental factors important to vegetation growth, community structure and function, terrestrial birds, small mammals, terrestrial and semi-aquatic furbearers, and browse productivity and utilization by ungulates were evaluated. Plot data were extrapolated using air photo interpretation and extensive ground truthing to assist in producing an ecosystem map at a scale of 1:25,000. The understanding of ecosystem function and structure formed the basis for: (1) assessment of capability for agriculture; (2) rating of forest capability and correlation of forest productivity; and (3) evaluation of wildlife habitat importance.

Land capability and habitat importance were presented as single theme maps produced by interpretation of the units on the ecosystem map. This approach to inventory and capability assessment provides a unified planning data base useful for environmental impact assessment and mitigation, facility planning, development and reclamation planning, and design of monitoring programs.

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- (1) L. Knapik, Pedocan Land Evaluation Ltd., Sherwood Park, Alberta
(2) D. A. Westworth, D. A. Westworth & Associates Ltd., Edmonton, Alberta
(3) A. W. Fedkenheuer, NOVA, AN ALBERTA CORPORATION, Calgary, Alberta
(4) S. E. Stephansson, Canstar Oil Sands Ltd., Calgary, Alberta

INTRODUCTION

During recent years, a number of integrated, interdisciplinary approaches to ecological resource inventories have been developed, including the Biophysical Land Classification (Subcommittee on Biophysical Land Class., 1969; Walmsley and van Barneveld, 1977a, b), Ecological Land Classification (ELC) (Jurdant et al., 1974; Env. Cons. Serv. Task Force, n.d.; Wiken et al., 1980a,b) and Biogeoclimatic Inventory (Krajina, 1965; Brooke, Peterson and Krajina, 1970; Klinka, Nuszdorfer and Skoda, 1979). In many cases these surveys have also been used as the basis for determining land capability ratings (Res. Eval. Branch, 1979; Walmsley and van Barneveld, 1977b; Klinka et al., 1980). Each of these inventory systems involve integration of surficial geology, soils, and vegetation components. The Biophysical and ELC approaches rely heavily on aerial photograph interpretation and limited field sampling to develop inventory maps. The Biogeoclimatic approach relies heavily on plot sampling and classification of sites rather than mapping. The wildlife component and habitat requirements are usually not considered during the classification and mapping procedure and in only a few cases are they correlated later.

The procedure developed and used by the authors for an ecological resource inventory of the Calumet Leases in northeastern Alberta included consideration of geology, soils, vegetation and terrestrial wildlife components for classifying and mapping ecosystems. The approach involved intensive sampling, air photo interpretation and ground truthing to extrapolate plot data to a map base. The ecosystem inventory was used as a basis for rating land capability for agriculture, forestry, and wildlife habitat importance using a common land unit base.

OBJECTIVES

The overall objectives of this project were to provide:

- (1) an integrated ecological resource inventory of landforms, soils, vegetation, forest resources, and wildlife habitat; and
- (2) an assessment of land capability for agriculture; forest capability; present forest productivity; and wildlife habitat importance.

APPROACH

The approach chosen was an ecosystem inventory which would provide a natural integration of factors controlling the structure and function of soil-vegetation-wildlife communities. Factors of importance to each of the components were to be identified and correlated to differentiate functioning units.

The ecosystem approach was chosen because it has several advantages over single theme inventories. The major advantage is that the pedologists, plant ecologists and wildlife biologists work together through all phases of the project to provide true integration of the disciplines. There are also several logistical advantages to having one co-ordinated survey team. It means there is one integrated report; one set of inventory maps with a common scale and presentation; and a data set based on standardized sampling at common sample sites. The inventory included a series of color maps at a scale of 1:25,000 depicting Ecosystem Units, Soil Units, Wildlife Habitat Importance, Capability for Agriculture and Capability for Forestry.

METHODS

Sampling

The inventory was conducted on the Calumet Leases, a 120 sq. km area being assessed for possible future oil sands development by Canstar Oil Sands Ltd. The Calumet Leases are situated approximately 80 km north of Fort McMurray, adjacent to the Athabasca River and bounded on the west side by the Birch Mountains (Figure 1).

Field investigations were carried out from June to October 1981 by field teams composed of a pedologist, a plant ecologist and a wildlife biologist. Procedures for recording information on site conditions, soils, vegetation and forest mensuration followed those described in the manual "Describing Ecosystems in the Field", prepared by the British Columbia Ministries of Forests and Environment (Resource Analysis Branch, 1980). Procedures for recording wildlife data were modified to accommodate the range of species present in the area and to be consistent with other wildlife investigations being conducted on the Calumet Leases. All inventory data were coded in the field and entered into a computer for compilation, sorting and analysis.

Field sampling was done at two levels of intensity. A reconnaissance sampling program was initially conducted to identify and describe vegetation and soil types at 300 sites distributed over the entire study area. Sites were selected to be representative of the various landforms, soil types, parent

materials and vegetation types present in the area. This sampling provided differentiation criteria to classify vegetation types and soil units and provided the basis for the detailed sampling. A soil unit/vegetation type matrix was derived showing the combinations of soil units and vegetation types identified in the reconnaissance portion of the study.

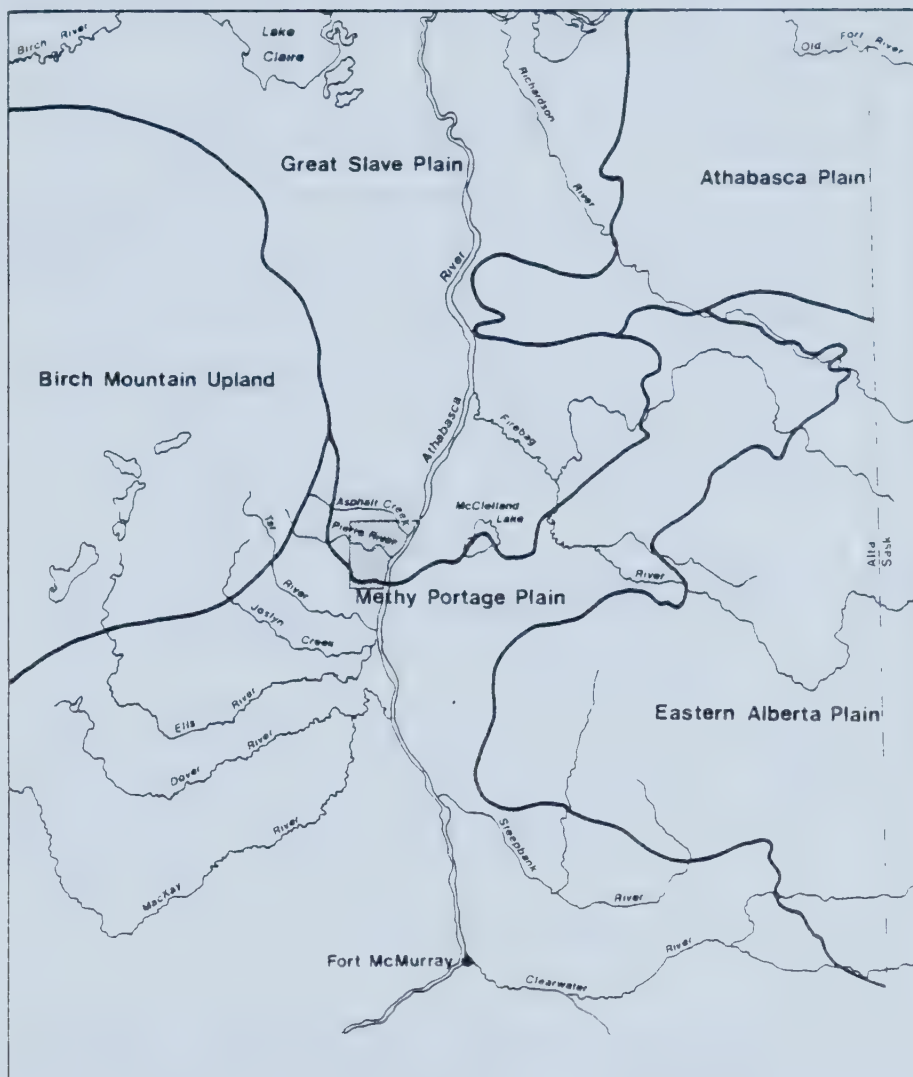


Figure 1. Location of the Study Area in Relation to Physiographic Units in the Region (after Pettapiece, 1981).

Detailed sample plots were subsequently selected to represent the soil/vegetation combinations found on the study area. A total of 115 sites were selected.

Plot selection criteria included: (1) representativeness of the ecosystem; (2) replication of the more commonly occurring ecosystems; (3) distribution of plots over the leases; (4)

homogeneity of the site; and (5) wildlife habitat and range criteria. Plots were located so that single soil polypedons and single plant communities were sampled in locations with homogeneous site factors. The design of a detailed sample plot is shown in Figure 2.

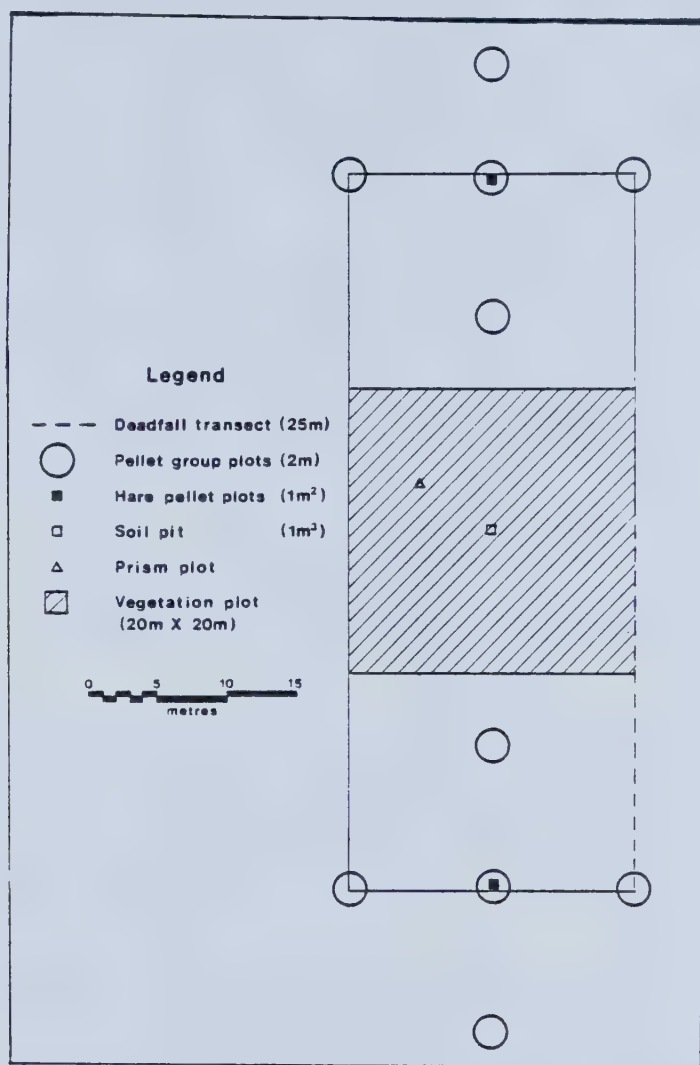


Figure 2. Detailed Sample Plot Design.

Wildlife data collection included the measurement of parameters required to assess wildlife use and habitat capability. For ungulates this included measurements of browse availability and utilization, pellet group counts and measurements of vegetation cover values. Habitat use by furbearers was assessed by systematically searching a 20 m x 50 m plot at each detailed sample site for sign. Types of sign included the presence of dens, tracks, scats, middens and bear diggings. Snowshoe hares, the staple prey item of lynx and fisher (the most commercially

important terrestrial furbearers in this region), were assessed by recording browse utilization and pellet densities. In addition to a point census for avifauna at each detailed sample site, transect surveys were conducted through representative ecosystem types for terrestrial breeding birds. Waterfowl surveys were conducted along major streams and lakes in the area. Amphibians and reptiles were censused in the 10 plots used to count ungulate pellet groups at each detailed sample site.

ECOSYSTEM CLASSIFICATION AND MAPPING

Classification of ecosystems is an abstract process whereby individuals or groups of a population are assigned to classes or taxa. Ecosystem mapping involves delineation of real patterns of ecosystems that occur in the landscape. The patterns of components that make up a mapped unit (Ecosystem Unit) may be simple or complex, but they occur together in the landscape and can be delineated and defined as having a certain range of characteristics.

Identification and mapping of ecosystems involved two major steps:

1. Identification of "ecosystems" or "biogeocoeonotic types" based on data obtained from reconnaissance and detailed sampling of soils, vegetation, and wildlife habitat.
2. Mapping of ecosystem units by delineating ecosystems (or patterns of ecosystems in complex areas) on aerial photographs, followed by ground truthing. Criteria used to discriminate or separate ecosystem types included an evaluation of parameters important to key species of wildlife.

ECOSYSTEM COMPONENTS

The general patterns of landforms, surficial materials, soils, and vegetation correspond to the ecodistricts of Turchenek and Lindsay (1981) which reflect minor regional differences in climate and ecosystem assemblages (Figure 3). Landforms, surficial materials and soil units common to each ecodistrict are summarized in Table 1 and are shown schematically for a portion of the area in Figure 4. Ecosystem units, vegetation types, and ecological moisture and nutrient regimes are also correlated in Figure 4.

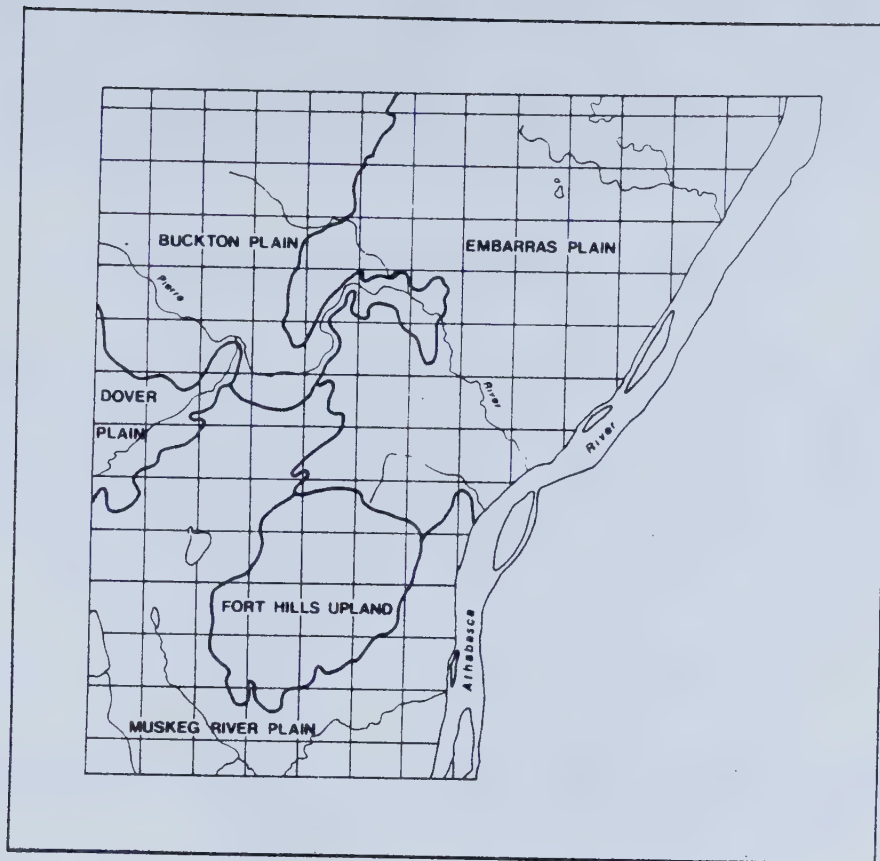


FIGURE 3. Ecodistricts of the Study Area.

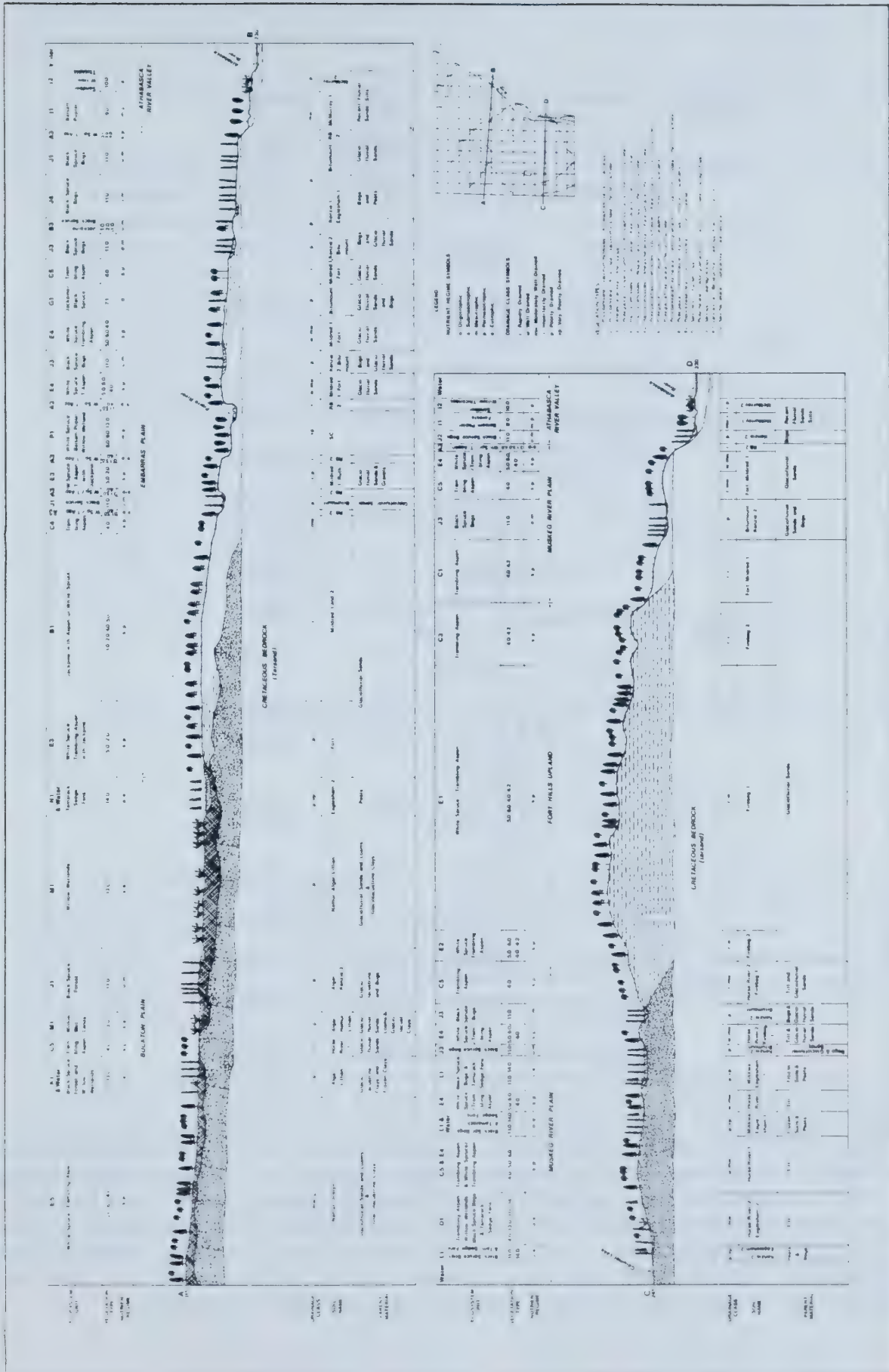


Figure 4. A Schematic Profile of a portion of the Study Area Showing the Relationship between Ecosystem Units, Vegetation Types, Soils, Nutrient Regime and Ecological Moisture Regimes.

Table 1. Major Terrain Features and Soil Patterns of the Study Area.

PHYSIOGRAPHIC DISTRICT	LANDFORMS	MATERIALS	MOISTURE REGIME	SOIL MAP UNITS
PORT HILLS UPLAND	hummocky glaciofluvial kame-delta	fine sands; with large pieces of till and bedrock	subseric to submesic	PTR1 (Firebag)
	very steeply sloping dissected glaciofluvial kame-delta	fine sands; with large pieces of till and bedrock	subseric to submesic	PTR2 (Firebag)
EMBARRAS PLAIN	undulating glaciofluvial plains	fine loamy fluvial sediments overlying glaciofluvial sands	mesic to submesic	FRT (Port)
	undulating to ridged glaciofluvial plain	fine loamy and sandy fluvial sediments overlying sands and gravelly sands	mesic to submesic	FRT-RUT (Port-Ruth Lake)
	undulating glaciofluvial plains	fine and medium glaciofluvial sands	submesic to subseric	MIL1 (Mildred)
	blanket and plateau bogs interspersed with horizontal fens	bog and fen peat	subhydryc to hydryc	KNE1-BGL1 (Kenzie-Eaglesham)
	discontinuous veneer bogs and undulating glaciofluvial plain	bog peat veneer over sands	hydryc to subhydryc	KNE2-BMT (Kenzie-Bitumount)
	undulating glaciofluvial plains	discontinuous fine loamy fluvial sediments over glaciofluvial sands	mesic to subseric	FRT-MIL1 (Port-Mildred) MIL1-FRT (Mildred-Port)
BUCKTON PLAIN	level lacustrine plain	clays and silty clays with inter-layered sands	hygric	ALG-LLN (Algar-Lillian)
	undulating to level fluvial and lacustrine plains	silty clays, loams and clays with interlayered sands	eubhygric	NMN-ALG (Nemur-Algar)
	level lacustrine plain with discontinuous veneer bogs	clays and silty clays with thin bog peat veneers	hygric	ALG-KNE3 (Algar-Kenzie)
	horizontal fen with plateau bog islands	fen and bog peat	subhydryc to hydryc	BGL1-MNM (Eaglesham-Mikmaa)
DOVER PLAIN	level lacustrine and fluvial plain and lacustrine blanket over undulating morainal	clays and silty clays with sandy layers; and clays overlying clay loam till	subhygric	NMN-JSN (Nemur-Joelyn)
	undulating to rolling morainal plain	thin sandy and silty veneers overlying clay loam till	mesic	HRR1-HRR2 (Horse River)
	level lacustrine plain	clays and silty clays	hygric	ALG (Algar)
MUSKOG RIVER PLAIN	undulating to rolling morainal plain	thin sandy and silty veneers over clay loam till	mesic	HRR1 (Horse River)
	undulating glaciofluvial plain	discontinuous fine loamy fluvial over glaciofluvial sands	mesic to subseric	FRT-MIL1 (Port-Mildred)
	discontinuous blanket and veneer bogs over glaciofluvial sands	discontinuous bog peat over sand	subhydryc to hygric	KNE2-BMT (Kenzie-Bitumount)
	rolling to hilly complex morainal and kame-delta upland	clay loam till and glaciofluvial sands	mesic to submesic	HRR2-PTX (Horse River-Firebag)

Classification of vegetation using a tabular comparison of vegetation releves (Mueller-Dombois and Ellenberg, 1974) resulted in the identification of 18 vegetation types in the Calumet Leases (Table 2). Vegetation types were subdivided into variants to recognize consistent differences in floristic composition evident in the ground vegetation, but not discernible in the tree layer. The vegetation types and variants were named according to the most characteristic species in the vegetation layers present.

TABLE 2. Vegetation Types Identified in the Study Area.

TYPE NO.	VEGETATION TYPE
1.0	<i>Pinus banksiana</i> — <i>Vaccinium myrtilloides</i> — <i>Arctostaphylos uva-ursi</i> — <i>Cladina</i> spp
2.0	<i>Pinus banksiana</i> — <i>Alnus crispa</i> — <i>Vaccinium vitis-idaea</i> — <i>Pleurozium schreberi</i>
3.0	<i>Amelanchier alnifolia</i> — <i>Artemisia</i> spp.
3.1	<i>Picea glauca</i> — <i>Juniperus communis</i> — <i>Arctostaphylos uva-ursi</i> — <i>Pleurozium schreberi</i>
4.0	<i>Populus tremuloides</i> — <i>Viburnum edule</i> — <i>Aralia nudicaulis</i> — <i>Pleurozium schreberi</i>
4.1	<i>Populus tremuloides</i> — <i>Rosa acicularis</i> — <i>Equisetum</i> spp. — <i>Pleurozium schreberi</i>
4.2	<i>Populus tremuloides</i> — <i>Amelanchier alnifolia</i> — <i>Aralia nudicaulis</i> — <i>Pleurozium schreberi</i>
5.0	<i>Picea glauca</i> / <i>Populus tremuloides</i> — <i>Viburnum edule</i> — <i>Aralia nudicaulis</i> — <i>Hylocomium splendens</i>
6.0	<i>Picea glauca</i> — <i>Viburnum edule</i> — <i>Cornus canadensis</i> — <i>Hylocomium splendens</i>
7.0	<i>Picea glauca</i> / <i>Picea mariana</i> — <i>Pleurozium schreberi</i>
7.1	<i>Pinus banksiana</i> / <i>Picea mariana</i> — <i>Ledum groenlandicum</i> — <i>Vaccinium vitis-idaea</i> — <i>Pleurozium schreberi</i>
8.0	<i>Picea glauca</i> — <i>Viburnum edule</i> — <i>Equisetum</i> spp. — <i>Hylocomium splendens</i>
9.0	<i>Populus balsamifera</i> — <i>Cornus stolonifera</i> — <i>Equisetum pratense</i>
10.0	<i>Salix interior</i> — <i>Equisetum</i> spp.
11.0	<i>Picea mariana</i> — <i>Ledum groenlandicum</i> — <i>Vaccinium vitis-idaea</i> — <i>Sphagnum</i> spp.
13.0	<i>Salix</i> spp. — <i>Calamagrostis</i> spp.
14.0	<i>Larix laricina</i> — <i>Betula pumila</i> — <i>Carex</i> spp. — <i>Aulacomnium palustre</i>
15.0	<i>Salix maccalliana</i> — <i>Typha latifolia</i> — <i>Carex vesicaria</i>

Table 3 summarizes the relationship of soils and vegetation types to ecosystems in a matrix form.

ECOSYSTEM MAP UNITS

The mapping procedure resulted in the identification of 40 ecosystem units (Table 4). These units vary from being relatively simple in terms of vegetation and soils components to being complex assemblages of several vegetation types and soil units. This is a reflection of the heterogeneous nature of some landscapes and the need for grouping small units at the scale of mapping used in this study (1:25,000).

The ecosystems of the Calumet Leases cover a wide variety of nutrient and moisture regimes (Figure 5). Moisture regimes range from very xeric to hydric, with mesic and hygric to sub-hygric regimes being most common. Nutrient regimes are dominantly sub-mesotrophic to mesotrophic on upland sites and oligotrophic in bogs. Both moisture and nutrient regimes have an important bearing on the capability of the land for growing vegetation and supporting wildlife.

Table 3. Relationship of Soil Groups and Units to Vegetation Types and Correlation to Ecosystem Units in Which the Ecosystem Components Were Mapped. Ordering of Soil Units and Vegetation Types is From Xeric to Hydric.

Soil Group/Unit	Vegetation Type																		
	1.0	2.0	3.0	3.1	4.0	4.1	4.2	5.0	6.0	7.0	7.1	8.0	9.0	10.0	11.0	13.0	14.0	15.0	
Mildred /MIL1	B1,B3	B1,B2 B3			B1,C4 D1		C1	B1											
Mildred /MIL2	B1	E3						E3											
River Bank 1/RB1																			
River Bank 2/RB2			A2	A3	A3			A3											
Ruth Lake /RUT					E5														
Firebag /FIR1					C2,E1		E1	E1	E1										
Firebag /FIR2					C3,E2		C3,E2	E2	E2										
Fort /FRT		B2			B1,B2 C1,C5 D1,E3 E4			B2 A1,E4	E4,F1										
Horse River/HRR1					C5,D1 E4			E4	E4,F1										
Horse River/HRR2					C5,D1 E4			E4	E4,F1										
Joslyn /JSN					E5	C6		E5	E5										
Dover /DOV					E5	C6		E5	E5										
Namur /NAM					E5			E5	E5										
McMurray /MMY1												H2	H2,I1						
McMurray /MMY2														I2					
Ells River /ELS												H1			J1				
Lillian /LLN															J1,K1				
Algar /ALG						C6,D2				D2		H1			J1,J3 K1	D1,D2 K1,M1			
Bitumount /BNT										D2	G1	H3			B3,D1 J1,J3				
Kenzie /KNZ1															D1,D2 J3,J4 L1				
Kenzie /KNZ2					D1										B3,D1 D2,J2 J3				
Kenzie /KNZ3															D1,D2 H3,J3 K2				
Mikkwa /MKW															J3,J4 L1				
Eaglesham /EGL1																M2	D1,L1 N1,P3		
Eaglesham /EGL2																K1,M2	D1,P3		
Stream Channel/SC													P1	P1		P1,P2		P3	

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Table 4. Ecosystem Units of the Study Area.

RIVER BANKS	A1	Unvegetated rock outcrops on the banks of the Athabasca River (RB1 soil unit)	JACKPINE / BLACK SPRUCE	F1	Mesic white spruce forest (6.0) on Orthic Gray Luvisols (Fort Horse River)
	A2	Saskatoonberry-sage (3.0) on shallow Regosolic soils (RB2) on xeric southfacing banks of the Calumet River		G1	Hygic jackpine/black spruce forest (7.1) on sandy Gleysols (Bitumount) and Gleyed Luvisols
	A3	Complex of mesic white spruce-aspen forest (5.0), white spruce forest (6.0, 3.1) and aspen forest (4.0) on Regosolic soils (RB2) on steeply sloping river banks		H1	Hygic white spruce forest (8.0) on clayey Gleysols (Algar, Elis River)
JACKPINE FOREST	B1	Xeric jackpine forest (1.0, 2.0) with inclusions of aspen (4.0) or white spruce-aspen (5.0) on sandy Eluvial Dystric Brunisols (Mildred) on the plains	HYGIC WHITE SPRUCE FOREST	H2	Hygic white spruce forest (8.0) and balsam poplar forest (9.0) on Regosols and Gleysols (McMurray) on fluvial flood plains
	B2	Mesic jackpine forest (2.0) with inclusions of aspen (4.0) or white spruce-aspen (5.0) on Orthic Gray Luvisols (Fort) on the plains		H3	Complex of hygic white spruce forest (8.0) on peaty Rego Gleysols (Bitumount) and black spruce bog (11.0) on Terric Mesosols (Kenzie)
	B3	Complex of jackpine forest (1.0, 2.0) on sandy Eluvial Dystric Brunisols (Mildred) and black spruce bog (11.0) on Organic (Kenzie) soils		I1	Balsam poplar forest (9.0) on Cumulic Regosols (McMurray MMY1)
ASPEN FOREST	C1	Mesic aspen forest (4.0) on Orthic Gray Luvisols (Fort) with inclusions of xeric aspen (4.2) on sandy Eluvial Dystric Brunisols (Mildred) and Lithic Brunisols	ATHABASCA RIVER TERRACES	I2	Sandbar willow (10.0) on Fluvial Rego Gleysols (McMurray MMY2)
	C2	Mesic aspen forest (4.0) on sandy Eluvial Dystric Brunisols (Firebag-FIR1) on the Fort Hills		J1	Black spruce forest (11.0) on peaty Gleysols (Bitumount, Elis River, Algar) and Gleysolic Static Cryosols (Lillian)
	C3	Mesic aspen forest (4.0) on sandy Eluvial Dystric Brunisols (Firebag-FIR2) on the escarpments of the Fort Hills		J2	Black spruce bog (11.0) on Terric and Fibric Mesosols (Kenzie)
	C4	Mesic aspen forest (4.0) on sandy Eluvial Dystric Brunisols (Mildred, Ruth Lake) on the plains		J3	Black spruce bog (11.0) on Terric and Fibric Mesosols (Kenzie) and Organic Cryosols (Mikwa) and peaty Gleysols (Bitumount, Algar)
	C5	Mesic aspen forest (4.0) on Orthic Gray Luvisols (Fort or Horse River) and Lithic Gray Luvisols on the plains	BLACK SPRUCE FOREST	J4	Black spruce bog (11.0) on Fibric Mesosols (Kenzie) and Organic Cryosols (Mikwa)
	C6	Hygic aspen forest (4.1) on clayey Gleysols (Algar) and Luvisols (Dover, Joslyn)		K1	Complex of black spruce forest (11.0) and willow wetland (13.0) on peaty Gleysols (Algar) and Gleysolic Static Cryosols (Lillian)
COMPLEX OF ASPEN FOREST AND WETLAND	D1	Complex dominated by mesic aspen forest (4.0) on Eluvial Dystric Brunisols (Mildred) and Orthic Gray Luvisols (Fort, Dover), with small areas of willow wetlands (13.0) on clayey Gleysols (Algar) or black spruce forest (11.0) on sandy Gleysols (Bitumount) and Organic (Kenzie) soils or tamarack-sedge fen (14.0) on Organic (Eaglesham) soils	BLACK SPRUCE FOREST / WILLOW WETLAND	K2	Complex of black spruce bog (11.0) and willow wetland (13.0) on Terric Mesosols (Kenzie, Eaglesham)
	D2	Complex dominated by hygic aspen forest (4.1) on clayey Gleysols (Algar) with small areas of black spruce bog (11.0) on Organic (Kenzie) soils or willow wetland (13.0) on Algar soils		L1	Complex of black spruce bog (11.0) on Typic Mesosols (Kenzie) and Organic Cryosols (Mikwa) and tamarack-sedge fen (14.0) on Typic Mesosols (Eaglesham)
MIXED WHITE SPRUCE/ASPEN FOREST	E1	Mesic white spruce-aspen forest (5.0) with inclusions of white spruce (6.0) and aspen (4.0, 4.2) on Eluvial Dystric Brunisols (Firebag-FIR1) on the Fort Hills	BOG FEN COMPLEX	M1	Willow wetland (13.0) on peaty Gleysols (Algar), Gleysolic Static Cryosols (Lillian) and Gleyed Regosols (Namur)
	E2	Mesic white spruce-aspen forest (5.0) with inclusions of white spruce (6.0) and aspen (4.0, 4.2) on Eluvial Dystric Brunisols (Firebag-FIR2) on escarpments of the Fort Hills		M2	Willow wetland (13.0) on Typic Mesosols (Eaglesham) and Organic Cryosols (Mikwa)
	E3	Mesic white spruce-aspen forest (5.0) with inclusions of jackpine (2.0) on sandy Eluvial Dystric Brunisols (Mildred and Ruth Lake)	WILLOW WETLAND	M3	Complex of willow wetland (13.0) on peaty Gleysols (Algar) and Gleysolic Static Cryosols (Mikwa) and tamarack-sedge fen (14.0) on Terric Mesosols (Eaglesham)
	E4	Mesic white spruce-aspen forest (5.0) with inclusions of white spruce (6.0) and aspen (4.0) on Orthic Gray Luvisols (Fort and Horse River)		N1	Tamarack-sedge fen (14.0) on Typic Mesosols (Eaglesham)
	E5	Mesic white spruce-aspen forest (5.0) with inclusions of white spruce (6.0) and aspen (4.0) on clayey Luvisols (Dover, Joslyn) and clayey Gleyed Regosols (Namur)		P1	Complex of hygic white spruce forest (8.0), balsam poplar forest (9.0) and willow wetland (13.0) on fluvial Regosols and Gleysols (McMurray and SC soil unit)
MIXED WHITE SPRUCE/ASPEN FOREST			STREAM CHANNELS	P2	Willow wetland (13.0) on fluvial Gleysols on flood plains (SC soil unit)
				P3	Sedge fen (14.0) and aquatic vegetation (15.0) on fluvial Gleysols and Terric Mesosols on flood plains (SC soil unit)

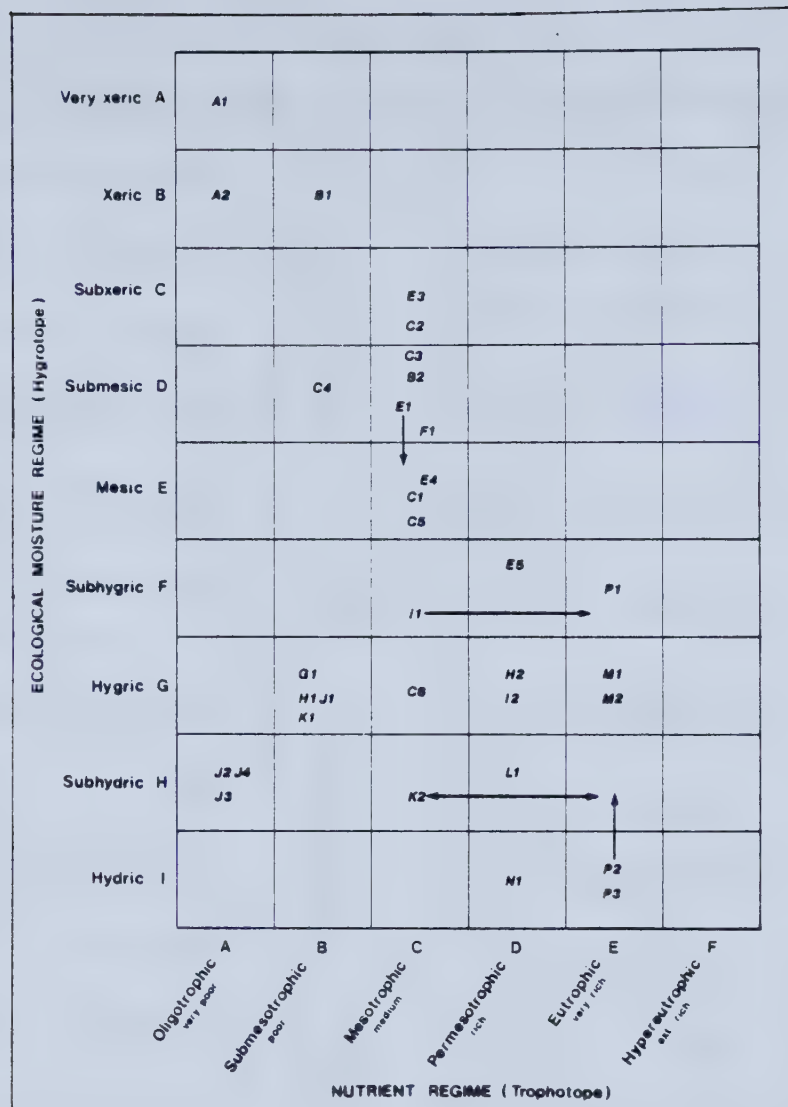


Figure 5. Relationships of Ecosystem Units to Moisture and Nutrient Regimes.

WILDLIFE HABITAT EVALUATION

To examine habitat use by a wide range of wildlife species, it was necessary to employ a number of study methods. These methods provided indices of animal density (e.g., call count transects and snap trapping), of animal use (e.g., browse utilization and pellet group counts) and of capability for supporting populations (e.g., browse availability). In order to provide a basis for classifying the land and for delineating important habitat areas, a habitat importance index was calculated for each species or group of species based on all applicable data. Vegetation types and ecosystem units were placed in one of five importance classes by

dividing the range in indices of habitat importance (from zero to the highest index calculated) into five intervals of equal width:

Class 1:	Excellent
Class 2:	Good
Class 3:	Moderate
Class 4:	Poor
Class 5:	Very Poor

In assessing the overall importance of ecosystems present in the study area for wildlife, emphasis was placed on four major faunal groups (birds, ungulates, semi-aquatic furbearers and terrestrial furbearers). These groups are considered key faunal components of the area either because of their economic importance or their abundance.

A matrix summarizing the habitat importance ratings for these key groups of wildlife is depicted in Figure 6. The overall high importance of the area for wildlife reflects the high diversity and interspersed landforms and vegetation types which provide productive habitats for a large diversity of wildlife species.

An important point to be considered is the applicability of an integrated ecological inventory as a basis for wildlife habitat assessment. Wildlife biologists have traditionally used overstory vegetation as the primary or sole criterion for distinguishing habitat types. This is primarily a mapping convenience since biologists have long been aware that other factors such as floristic composition of the shrub and herb layers, moisture regime, nutrient regime, slope and aspect affect habitat capability and wildlife use.

An integrated inventory enables habitat units to be classified and mapped in much greater detail. The advantages of this were apparent on the study area when particular forest types were examined. For example, seven aspen dominated ecosystem types were delineated on the Calumet Leases. These types varied widely in their use by major groups of wildlife (Table 5). The differences in capability and use resulted in significant differences in habitat importance ratings between aspen ecosystem types (Table 6). The variation in habitat importance ratings between aspen types is greater than the differences between many of the other ecosystems. This type of detailed examination enables important habitat areas to be defined with greater precision which in turn allows environmental planners to reduce adverse impacts to wildlife to a greater extent than possible with conventional habitat mapping procedures.

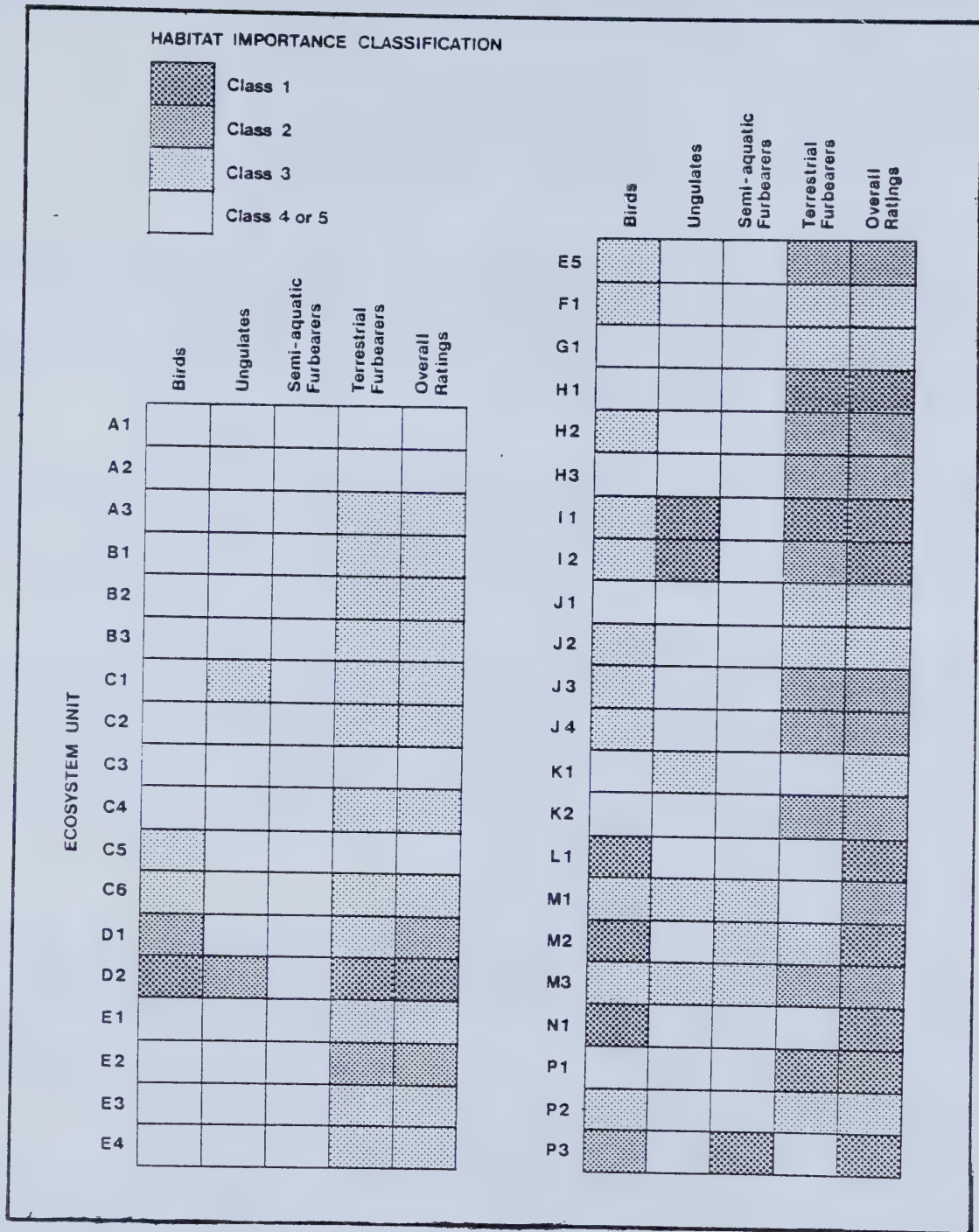


Figure 6. Summary Matrix Showing Wildlife Habitat Importance Ratings for Ecosystem Units on the Calumet Leases.

Table 5. Wildlife Use and Browse Availability in Aspen Forests.

Ecosystem Unit	Terrestrial Birds		Browse Availability (twigs/ha)		Pellet Group Counts	
	No. Species	Birds/ 100 ha	Hare	Ungulate	Hare Pellets/m ²	Moose PG/ha
C1	6	155	5,620	39,040	2.7	5.5
C2	6	178	9,860	4,580	1.5	1.0
C3	10	163	13,240	2,820	7.2	12.1
C4	9	208	11,910	10,230	12.6	1.0
C5	14	409	12,900	12,900	9.8	1.0
D1	7	295	9,830	8,830	4.9	1.0
D2	9	221	58,860	58,860	24.0	1.0

Table 6. Habitat Importance Ratings for Aspen Forests.

Ecosystem Units	Terrestrial Birds	Ungulates	Terrestrial Furbearers
C1	3	3	3
C2	3	5	3
C3	3	5	4
C4	3	5	4
C5	1	4	3
D1	2	4	3
D2	3	2	1

AGRICULTURAL CAPABILITY

Soils were rated for agricultural capability according to the Canada Land Inventory guidelines (Canada Land Inventory, 1972). In this system, mineral soils are grouped into seven classes according to their limitations for agricultural use. The first three classes are capable of sustained production of common cultivated crops; the fourth class is considered marginal; the fifth is capable of use for improved pasture and hay production; the sixth is capable of use for unimproved pasture; and the seventh class has no capability or potential for agricultural use. Organic soils are not rated in the Soil Capability for Agriculture System, but they have very severe limitations, especially in this area, and were considered equivalent to Classes six and seven.

FOREST CAPABILITY AND PRODUCTIVITY

Capability ratings for forest productivity are based on the inherent ability of land to grow timber in commercial quantities (Alberta ENR, 1979). The classification system is composed of three major components:

- (1) A capability class is an expression of all environmental factors that apply to tree growth, including subsoil, soil, surficial expression, local and regional climate and characteristic tree species.
- (2) Capability sub-classes denote factors which limit forest productivity; and
- (3) Indicator species are the indigenous trees adapted to the region and site which can be expected to yield the tree volume associated with each class.

The soils map was used as the base for mapping forest capability. Information obtained on parent material, landform, topography and drainage, and soil parameters such as fertility, moisture regime, permeability, texture and depth to bedrock were used in the assessment of limitations to tree growth. This in turn led to the assignment of capability classes and sub-classes.

Forest productivity and CLI forest capability rating are generally based on the "present standing crop of merchantable coniferous timber" (Peterson and Levinsohn, 1977). Prokopchuk and Archibald (1976) state that, "guidelines for the establishment of plots were as follows; age between 80 and 140 years, 50 percent or more of the volume in soft woods (conifers) and a basal area greater than 150 square feet per acre (34 m²/ha) at 100 years." Predominantly young aspen forest cover in the study area does not conform to these sampling guidelines. Correlations of aspen productivity to white spruce productivity were made to evaluate forest productivity and capability.

Alberta Forest Service site index curves (modified by AFS from Macleod and Blyth, 1955) and data from Peterson and Levinsohn (1977) indicate that at 40 years of age, aspen should be from 50 to 60 percent taller than white spruce to maintain the same site index. At 60 years of age, aspen should be approximately 15 to 20 percent taller. Since the majority of aspen stands in the study area are between 40 and 50 years of age, a deciduous MAI reduction of 35 percent to yield the estimated white spruce equivalent was used to determine forest capability and productivity.

APPLICATION OF AN INTEGRATED ECOLOGICAL INVENTORY

The integrated ecological inventory is a valuable planning tool for resource projects including surface coal mining and oil sands developments, forestry, hydro developments and linear developments. It performs a variety of functions related to the information requirements for regulatory agencies, environmental impact assessment, and development and reclamation planning.

Facility Planning

An integrated data base is a valuable tool for use in site selection and design of facilities such as roads, pipelines, air strips, utility corridors, camps, plant sites, lagoons or tailings ponds, and sand and gravel quarries. The inventory is useful for identifying areas of environmental hazards such as areas that flood, areas with high water tables, unstable slopes and areas of permafrost. It also identifies environmentally sensitive areas such as important wildlife habitats (winter ranges, nesting areas, mineral licks, migration routes) and rare vegetation types or species. The data base also provides information on the location of sources of construction or reclamation materials such as sand, gravel, peat and clay.

Environmental Impact Assessment

This system provides a baseline inventory of environmental conditions in an area prior to development. It serves as a basis for assessing potential environmental effects of a development and for designing environmental protection procedures to mitigate adverse impacts. The baseline inventory includes information on the productivity and capability of sites, the location of environmentally sensitive areas and identifies rare or endangered species. It facilitates impact assessment by identifying environmental factors important for vegetation growth, community structure, and wildlife productivity.

Development and Reclamation Planning

An integrated ecological inventory also serves as a valuable tool for development and reclamation planning. It provides information on the existing productivity and capability of soils, vegetation and wildlife that can be used as a basis for selecting suitable end land uses. The soil survey and laboratory analysis provide data on the quantity, quality and distribution of materials for reclamation (peat, till, sand, clays). As well, the availability of plant species suitable for revegetation can be determined taking into account site requirements and importance for erosion control, wildlife food and/or wildlife cover. Again the

inventory provides a basis for identifying environmental factors important for vegetation growth, forest productivity, community structure, browse production and wildlife habitat. An understanding of these factors is essential for developing meaningful prescriptions for reclamation.

Monitoring Programs

The inventory provides a useful basis for designing environmental monitoring programs. Baseline information on soil quality can be used to assess the potential for soil acidification by acid-forming emissions. This information can also be used to assess post disturbance soil quality. The vegetation inventory provides baseline information on species composition and community structure. It can be used to select species that are useful as biological indicators of environmental changes and it is useful for selecting plots or sites to monitor the various types. During the wildlife inventory permanently marked sample sites can be established that are valuable for monitoring habitat use by ungulates, furbearers and important bird species. The inventory serves as a benchmark for measuring changes in browse productivity, biomass and nutrient content that are useful for monitoring effects on ungulate populations. It also provides information on the density of bird species that serve as useful biological indicators.

ADVANTAGES OF AN INTEGRATED APPROACH

There are several advantages to an integrated inventory and capability assessment. Perhaps the greatest advantage is that true integration of disciplines is possible when the various scientists work together through study design, sampling, data analysis, capability assessment and report presentation. This facilitates recognition of diagnostic factors for identifying ecosystems and understanding of important functional relationships between ecosystem components. The variation in browse productivity and hence wildlife habitat importance between different aspen types, and correlation of forest productivity to soil moisture and nutrient regimes were identified earlier as examples of relationships that otherwise may be missed in single discipline inventories.

The integrated approach also offers efficiencies in terms of logistics with one inventory team using one helicopter or other vehicle to produce one data set from common sample sites, and producing one report. Inventory and capability maps have a common base and scale and are derived from a common data base. This greatly facilitates use of the baseline inventory by development planners and review agencies.

An integrated approach with intensive sampling effort does however, require careful planning and design to be efficient and produce maximum use of the product. Careful identification of objectives and uses of the product is a prerequisite to design of sampling and data handling procedures. The amount of sampling and analysis largely controls the budget of the project; therefore, there are economic advantages to efficient design.

This type of an integrated approach has an inherent flexibility that allows for modification of techniques or the use of completely new techniques depending upon the particular information needs from the program. In another application the mapping scale could be changed to 1:10,000 thereby accommodating a more precise level of detail often required to interpret and manage ecologically diverse landscapes. A requirement for more detailed geotechnical information would lead to the collection of data not essential for impact assessment. However, that same data could provide the numbers to conceptually engineer habitat loss mitigation measures in a framework compatible with the regional environment.

Program planning the identification of specialist information that meets user needs is as important to obtaining the necessary results as is the E.L.C. assessment itself. The design of the program that was used for this study was time consuming in the early stages and required some adjustments after the teams were in the field. Later modifications were also made to the type of detail required for clarity and ease of interpreting the capability maps. The overall program successfully met land classification information needs and demonstrated the value of an integrated interdisciplinary approach to inventory and capability assessment.

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TOLERANCE OF FEATHER MOSSES TO BRINE SPILLS

Beverley A. Ross¹ and G. R. Webster²

Abstract

Compared with vascular plants, mosses represent an alternative strategy of adaptation to life on land. If reclamation procedures for forested areas are to be successful, one must know the native species. Methods for agronomic areas are not necessarily the best for forested areas. Results of 3 greenhouse experiments involving salt interactions with the feather mosses: Hylocomium splendens, Ptilium crista-castrensis and Pleurozium schreberi are presented.

Exposure time is not as critical as the Electrical Conductivity(E.C.) of the brine, in terms of moss damage. There is a significant difference in response patterns of the 3 feather mosses in all 3 experiments. Hylocomium splendens showed the largest and Ptilium crista-castrensis the smallest difference, between response patterns, to the osmotic effect of sorbitol and the osmotic plus salt effect of brine. Hylocomium is the most salt sensitive species. Under given conditions, calcium and/or potassium did not aid moss recovery when applied as a post flush treatment. Use of moss spores or fragments to 'seed' spill sites may be the most significant idea for field application.

INTRODUCTION TO MOSSES

There is a need to know more about the native forest species, especially if disturbed areas are to be returned to forest. Reclamation methods appropriate for agronomic areas may not necessarily be the best for forested areas (Innes and Webster 1981). As an example, an attempt to establish trees on a large disturbed area, seeded to grass, was next to impossible because of the greatly increased population of gnawing rodent. created by the grass cover (Sherstabetoff et al. 1978).

Until recently mosses have been a forgotten member of the forest ecosystem, with little known about their role in the forest or their basic physiology let alone their response to such things as brine spills. Feather mosses form thick mats, that protect the soil from erosion by wind and water. They play a role in the water relations of the forest floor cover by cushioning the impact of rain drops, redistributing the water and holding several times their dry weight in water. Unlike vascular plants most water movement in moss is external by capillary action along the plant segment, with their water content changing with that of the surrounding environment (Richardson 1981). Photosynthesis and respiration, in feather moss, continues until the water potential falls to about -55 to -100 bars and does not resume until the plant is remoistened (Busby and Whitfield 1978).

Compared with vascular plants, mosses, represent an alternative strategy of adaptation to life on land(Proctor 1979).

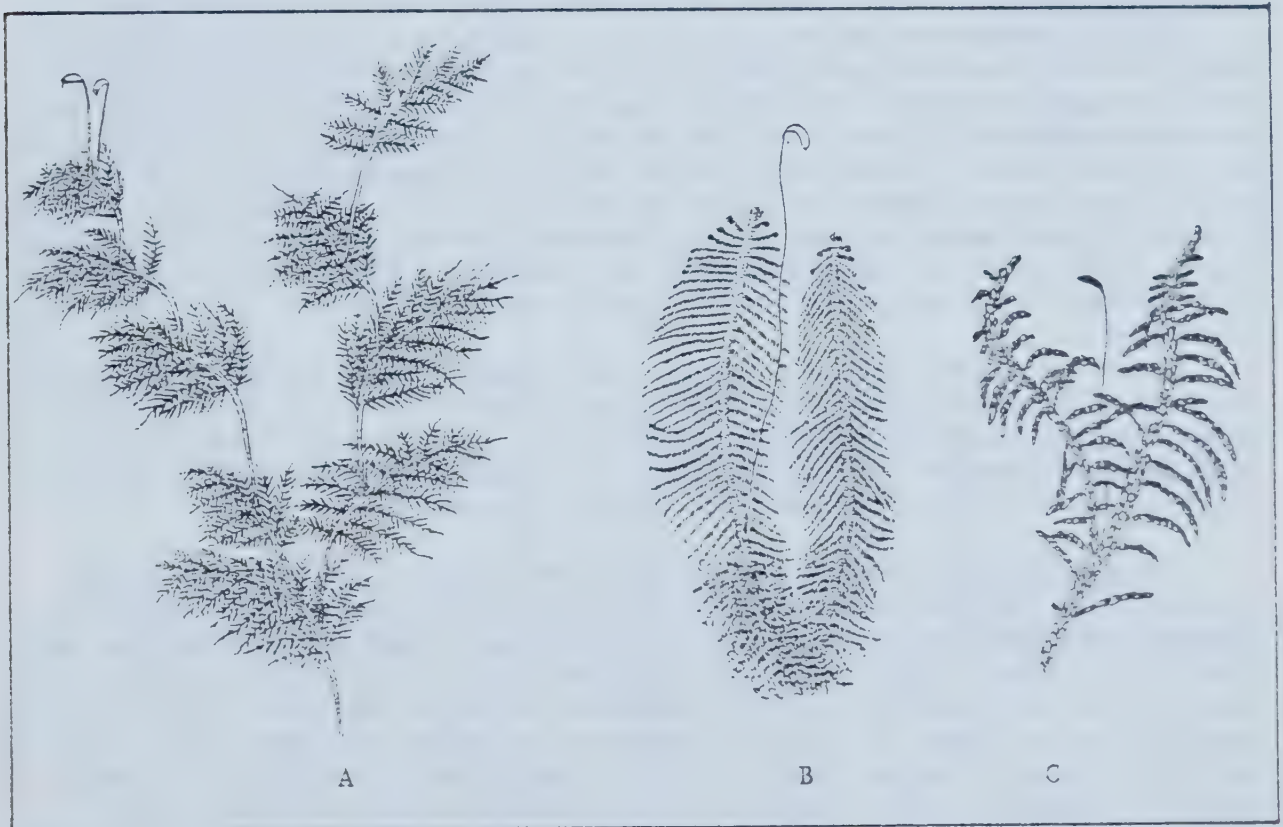
¹Graduate Student Dept. of Soil Science, University of Alberta.

²Dept. of Soil Science, University of Alberta, Edmonton, Alberta. T6G-2E1.

One of the most critical adaptations that mosses have made is the evolution of a protoplasm that can withstand extreme desiccation for relatively long periods (Anderson 1980). This type of adaptation is shared with lichens, many terrestrial algae, and such animals as tardigrades, nematodes and rotifers (Crowe 1971). This adaptation makes it very difficult to determine when a moss is 'dead', therefore most bryologists prefer the term inactive.

A second adaptation for survival is regeneration. In general, mosses produce vast numbers of spores e.g. Pleurozium schreberi fruits abundantly in Canada and a carpet of the moss may produce 10^8 healthy spores/m² (Longton 1976). However the sexual cycle of moss is so dependent upon water and so vulnerable to the changes of weather during critical phases that vegetative persistence is extremely crucial (Anderson 1980). Mosses have been said to exhibit more copious and varied means of vegetative reproduction than any other section of the plant kingdom (Sachs and Vines 1882). Fragments and even individual leaves, under ideal conditions, can regenerate into new plants.

Figure 1 Feather Mosses: (A) Hylocomium splendens
(B) Ptilium crista-castrensis (C) Pleurozium schreberi
(A+B) courtesy Noguchi 1976 (C) Landwehr and Barkman 1966 1976.



BRINE SPILL RECLAMATION IN FORESTED AREAS

A study of reclamation of brine spills in forest areas was conducted by Hardy Associates and G. R. Webster from 1977 to 1979 at 2 sites in the Swan Hills. Two publications by the Canadian Petroleum Association are the result of these studies, "Reclamation of Brine Spills in Upland Boreal Forest Areas, Part 1: Research and Part 2: Field Manual". Chapter 4 of Part 1 deals with a preliminary study of moss/salt relations.

Greenhouse Experiments

The following are some results of continued greenhouse studies of moss/salt relations on the 3 main mosses from the 2 Swan Hills sites. Collectively the 3 species are referred to as feather mosses (Figure 1), the individuals are: (A) Hylocomium splendens (Hedw.) BSG, sometimes called the Stair Step Moss, (B) Ptilium crista-castrensis (Hedw.) De Not. appropriately named the Knight's Plume, and (C) Pleurozium schreberi (Brid.) Mitt. a very common moss in North America (Crum 1976). Hylocomium and Ptilium are prevalent at Site 1 (LSD 10-16-67-10 W5M), a well drained area with white spruce, lodgepole pine, some fir and understory of low bush cranberry. Pleurozium is dominant at Site 2 (LSD 12-36-64-11 W5M), a poorly drained area with lodgepole pine, black spruce and understory of Labrador tea.

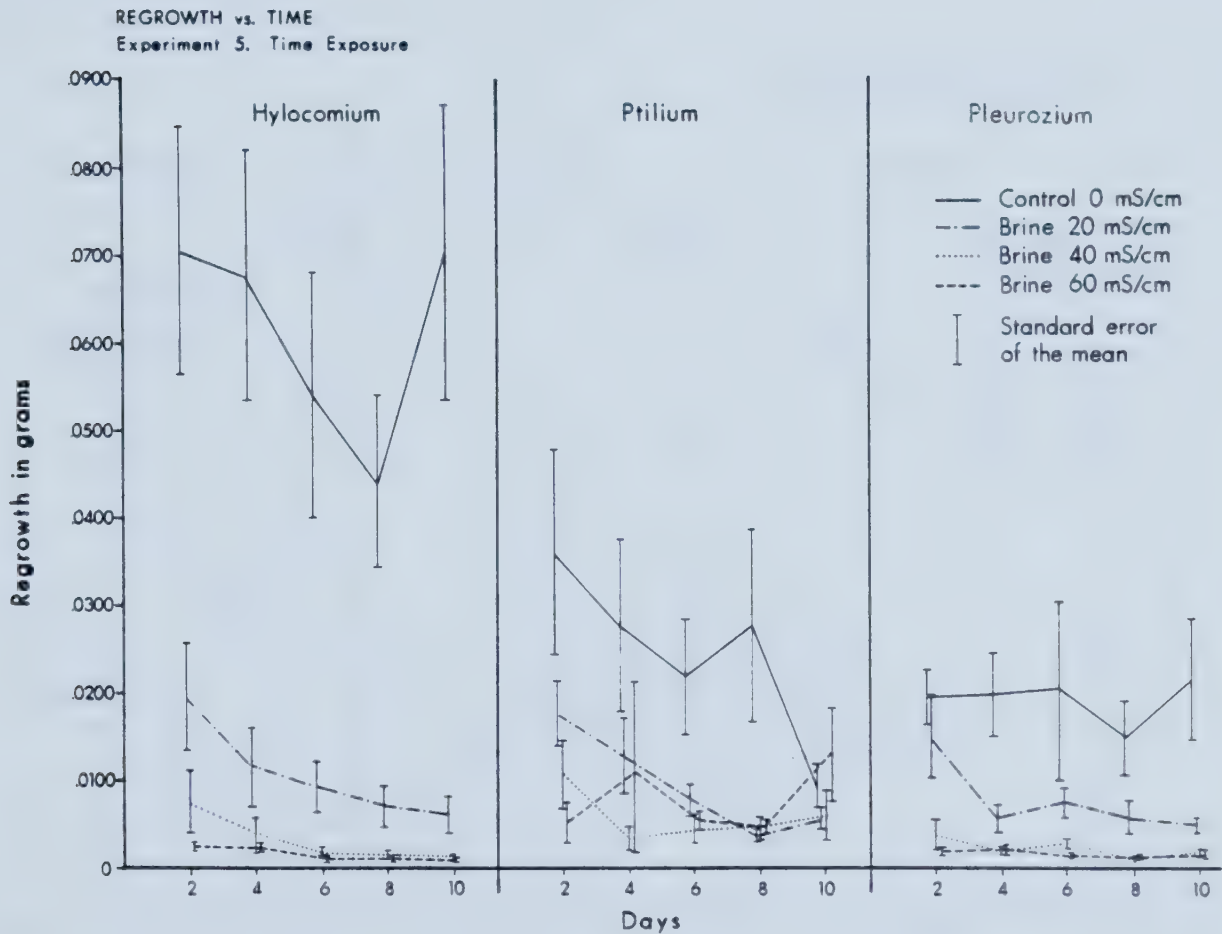
The 3 feather mosses were used in a series of greenhouse experiments, where 25 moss segments were made into bundles, and 6 bundles (replicates) used for each treatment. The brine used is from the Swan Hills formation, the main component is sodium chloride without any hydrogen sulfide present. In the experiments, a stress (brine or sorbitol) was applied to the moss bundle for a given amount of time, usually 72 hours, drained, then flushed with distilled water, a post flush treatment given (if applicable) and then plants were moved to the greenhouse for recovery. Mosses were misted with a 1/20 strength nutrient solution during the recovery period which varied from 25-30 weeks.

After recovery, regrowth biomass was clipped from the moss segments, dried over a saturated potassium acetate solution to a relative humidity of about 20% and weighed. Exposure to brine for 3 days, tests the plant's Salt SHOCK Tolerance and is different from Salt Tolerance (where a plant grows at a relatively constant E.C. level throughout its life).

Time Exposure: Exposure to stress was usually 3 days (a simulated minimum time lag from discovery of a spill in the field to the start of flushing operations). However in one experiment exposure time was varied from 2 to 10 days using 4 levels of brine from 0 to 60 mS/cm to determine the pattern of response. In Figure 2 Time Exposure, Regrowth vs Time, it is possible to see that the biggest change takes place between 2 and 4 days of exposure, in most cases. After 4 days of exposure the amount of recovery is similar, especially for the higher E.C. levels (40 and 60 mS/cm). The difference between brine levels is highly significant and the species/brine levels interaction is also highly significant. Hylocomium is the most sensitive of the 3 species. In Ptilium the increase in weight from day 8 to 10 at 60 mS/cm is in part due to colonization of the segments by other moss spores. The morphology of Ptilium is ideal for colonization because of its closely spaced branches which provide an even, moist surface for the spores.

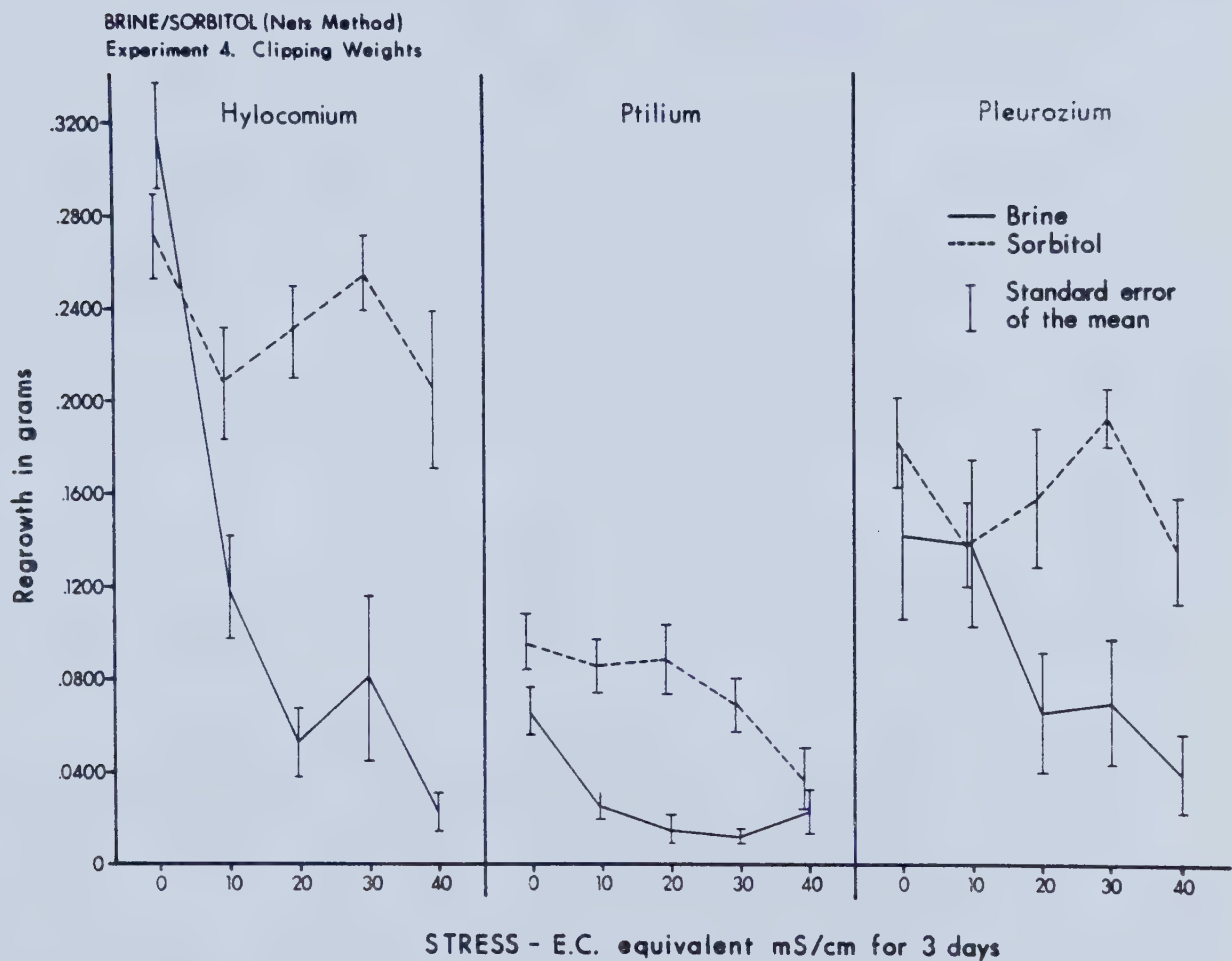
Although colonization is a nuisance in these experiments, the possibility of using it as a regenerative method to help reclaim a spill site may be the most significant idea, in terms of field application. Mosses, from unaffected areas near a spill site, could be pulverized and then added to the final water used in the flushing operations. This method of 'seeding' an affected area could be easily incorporated into the present reclamation procedures described by Innes and Webster 1981. This idea has not been tested in the field, as yet.

Figure 2.



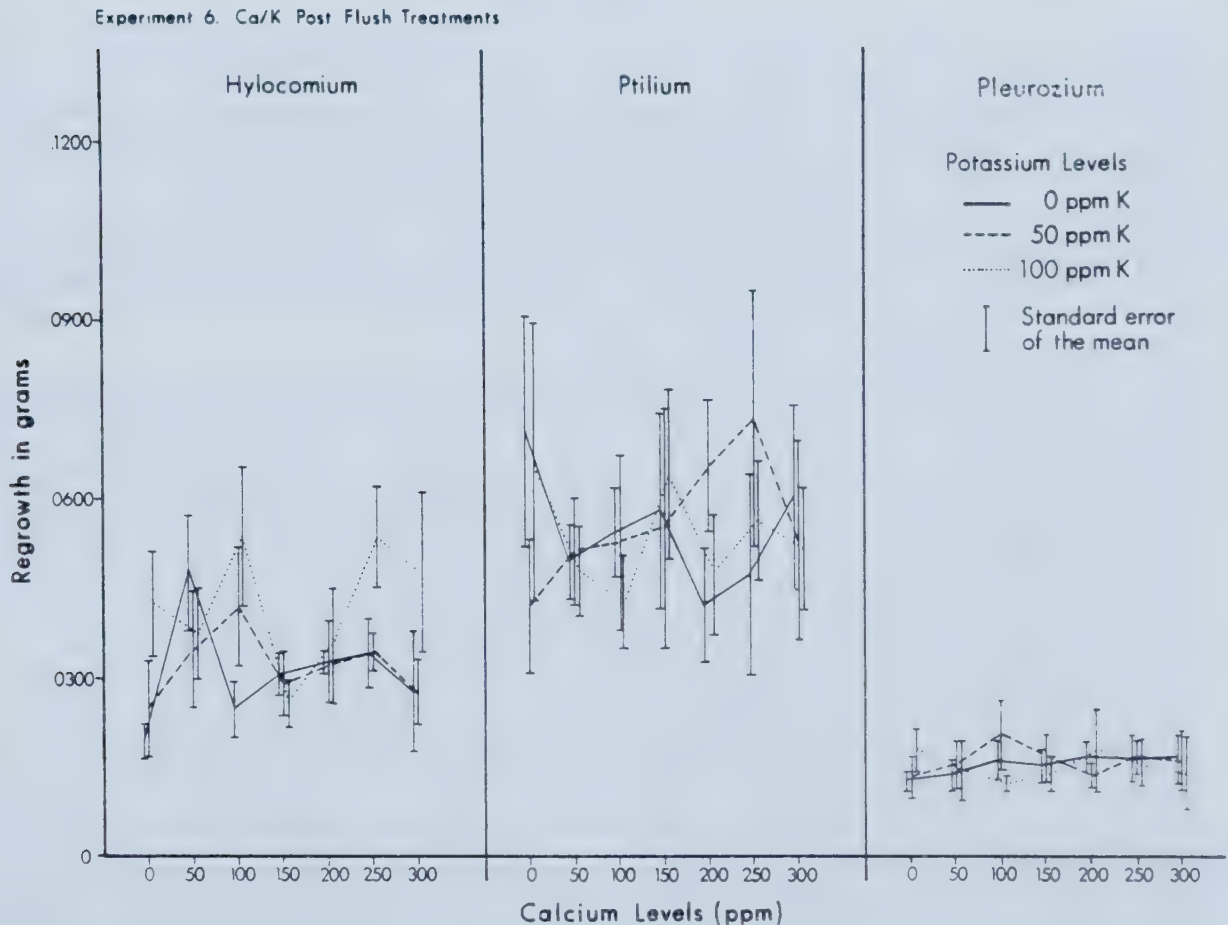
Brine/Sorbitol: Damage to plants by brine is caused by 2 main effects: the osmotic effect and the salt effect. Sorbitol, a sugar alcohol, is used to get the equivalent osmotic effect without the salt effect. Four stress levels with E.C. equivalents from 0 to 40 mS/cm are compared in Figure 3 Brine/Sorbitol. It is evident that the combined salt and osmotic effect of the brine is more harmful to the plants than the osmotic effect of the sorbitol. Differences among species are highly significant with Hylocomium showing the biggest difference and Ptilium showing the smallest difference between the 2 stress treatments. The differences between brine and sorbitol and the various levels of each are also highly significant.

Figure 3.



Calcium/Potassium Post Flush Treatments: In their experiments with moss and artificial seawater, Bates and Brown 1974, found that added calcium and potassium reduced the loss of intracellular potassium from the plants. To determine if calcium and/or potassium would aid moss recovery a factorial design, with 3 levels of potassium(K_2SO_4) and 7 levels of calcium($CaSO_4 \cdot 2H_2O$), was applied as post flush treatments after 3 days exposure to brine at 30 mS/cm. The response patterns of the 3 mosses are significantly different however there are no significant differences in any of the treatments in Figure 4 Ca/K Post Flush Treatments. It must be emphasized that nutrient solutions were used in this experiment, therefore interactions with the soil were not considered. In the field situation application of gypsum ($CaSO_4 \cdot 2H_2O$) to a spill site is beneficial to its overall reclamation.

Figure 4.



CONCLUSIONS BASED ON THESE EXPERIMENTS

- E.C. level of a brine spill is more critical than exposure time.
Damage to moss is caused by both osmotic and salt effects.
- Response patterns of the 3 feather moss species are different.
Hylocomium splendens is the most sensitive species.
- Calcium and/or Potassium under these conditions did not aid moss recovery.
- Use of colonization and regeneration of moss to help reclaim a spill site needs to be tested.

Acknowledgment

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GAS COMPOSITION IN THE UNSATURATED ZONE
AS AN INDEX OF GEOCHEMICAL EQUILIBRIUM
IN RECLAIMED LANDSCAPES
BY

Ed Wallick

ABSTRACT

This study is based on field work at the Battle River Mine area. The amount of oxygen and carbon dioxide in the gas in the unsaturated zone of reclaimed mine spoil is an indication of the type and level of geochemical activity of the water in the spoil. Potential for oxidation of organic matter and pyrite is indicated by the oxygen content; aggressiveness toward carbonate and silicate minerals is indicated by the carbon dioxide content. As these values approach the values observed in unmined landscapes, the reclaimed landscapes can be considered to have reached geochemical equilibrium.

INTRODUCTION

Land surface disturbance allows oxygen to come into contact with reduced carbon, sulfur, and nitrogen compounds. When oxidized, these compounds break down into CO_2 , SO_2 , and NO_2 gases which hydrolyze acidic. These acids are then available to attack silicate and carbonate minerals and contribute to the salt content of the rock. A soil salinization problem can develop if insufficient water is available for leaching of salts into the surface/groundwater systems.

Reclamation of overburden spoil involves reconstruction of the surface topography and soil profiles. However, the success of the reclamation effort is generally tied to the degree to which the landscape remains stable after contouring and planting. The problem is, then, how to determine if and when a particular landscape has reached physical-chemical equilibrium with its surroundings. The physical aspect of the problem generally focuses upon landscape settlement and this is also under examination by the PHRP¹. The question of whether a reclaimed landscape has reached geochemical equilibrium is addressed by this research regarding gas composition in the unsaturated zone.

We can define geochemical equilibrium as a condition where the rate of formation of a particular substance is in balance with the rate of removal. We could periodically examine the amount of salts present in the reclaimed spoil. We could even attempt to collect water samples in the unsaturated zone on a regular basis for time series analysis. The shortcoming with this approach is that sampling and analysis are expensive and noise problems severe due to the marked heterogeneity of the reclaimed spoil environment. Gases, however, mix freely in the unsaturated zone and collection and analysis are rather straightforward and inexpensive.

This research shows how monitoring of the gas composition in the unsaturated zones of natural and reclaimed areas can yield information regarding

¹ Plains Hydrology and Reclamation Program, Alberta Research Council

progress toward geochemical equilibrium. The carbon isotopic abundances in CO_2 were also measured and interpreted as to the source of the CO_2 and mechanism of production.

Significance

The return of reclaimed land to agricultural use in as short a time as possible is the most important reclamation objective. Therefore, a method which indicates the extent of geochemical equilibration of reclaimed spoil vs the natural setting will be useful to reclamationists who wish to refine the time estimate for turnover of land to farming.

Project Area

The research was conducted in the Battle River Project Area of Plains Hydrology and Reclamation Program. The area is located in figure 1.

OVERVIEW OF RESEARCH

The research was conducted in several phases during 1981 and 1982. Dry piezometers were installed in natural, undisturbed areas, in spoil piles, and in reclaimed spoil. Laboratory apparatus was constructed for evacuation of gas-sampling bulbs and for gas purification. Sampling and analysis of gas was conducted during the fall of 1981 and during the 1982 field season. Samples were analyzed for mole percent O_2 , N_2 , CO_2 , and SO_2 . Carbon dioxide was analyzed for the C-13/C-12 ratio.

Field Operations

Gas samplers were installed at the sites indicated on the map of the field area shown in Figure 2. Three of the sites were located in undisturbed areas where the unsaturated zone was especially thick. Two of these sites were located on bluffs adjacent to the Battle River (sites G1 and G2) and adjacent to Paintearth Creek (G3). The remaining sites were completed in reclaimed spoil (G4, G5, and G6). Site G7 was completed in a spoil pile. The gas samplers were nested at various depths in the unsaturated zone. Two inch PVC pipes were sealed into place as indicated in Figure 3. The details of the valve used to shut in the sampling pipe are also shown in Figure 3.

The shut in gas samplers were left undisturbed for a minimum of two weeks to permit the bulk of the atmospheric contamination introduced during drilling and pipe installation to dissipate.

Samples were collected by means of evacuated glass bulbs. The gas within the gas sampler pipe was permitted to expand into the evacuated 500 mL glass bulb by means of a manifold that had been evacuated on site with a small hand vacuum pump. The design of the manifold and sampling apparatus are shown on Figure 3.

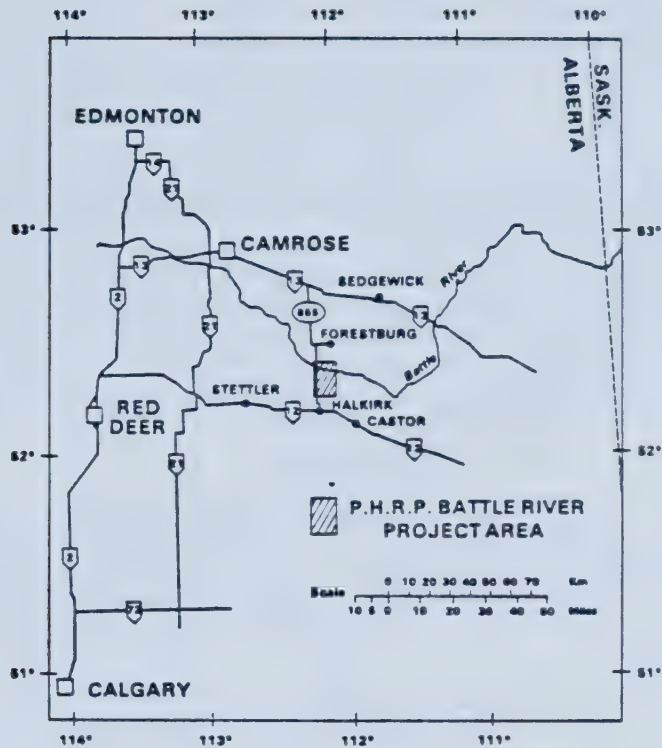


Figure 1. Location of PHRP study area.

Gas Sampling in the Field

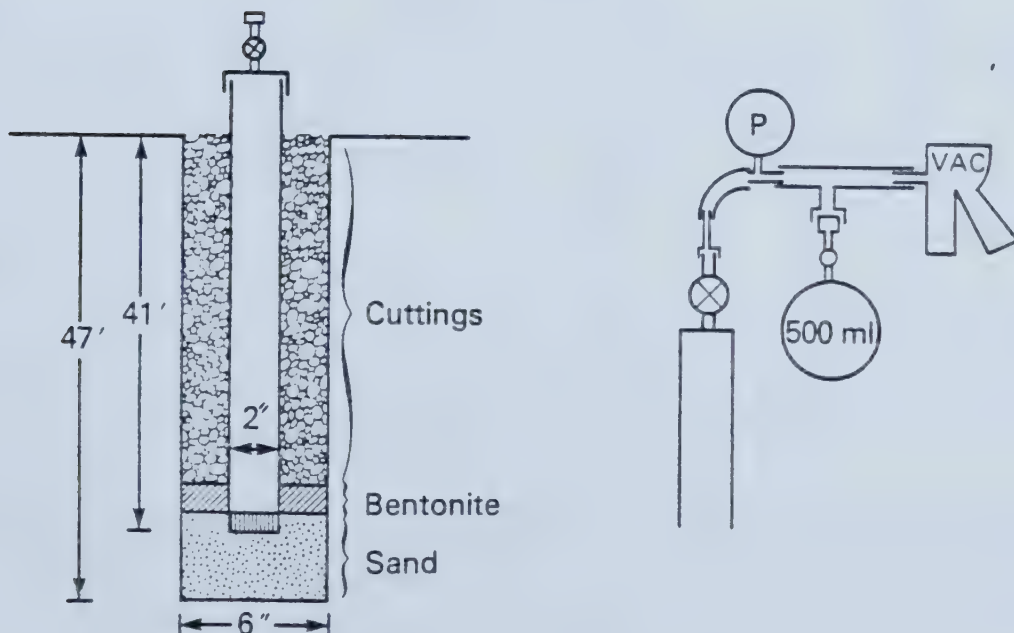


Figure 3. Gas sampling well and manifold.

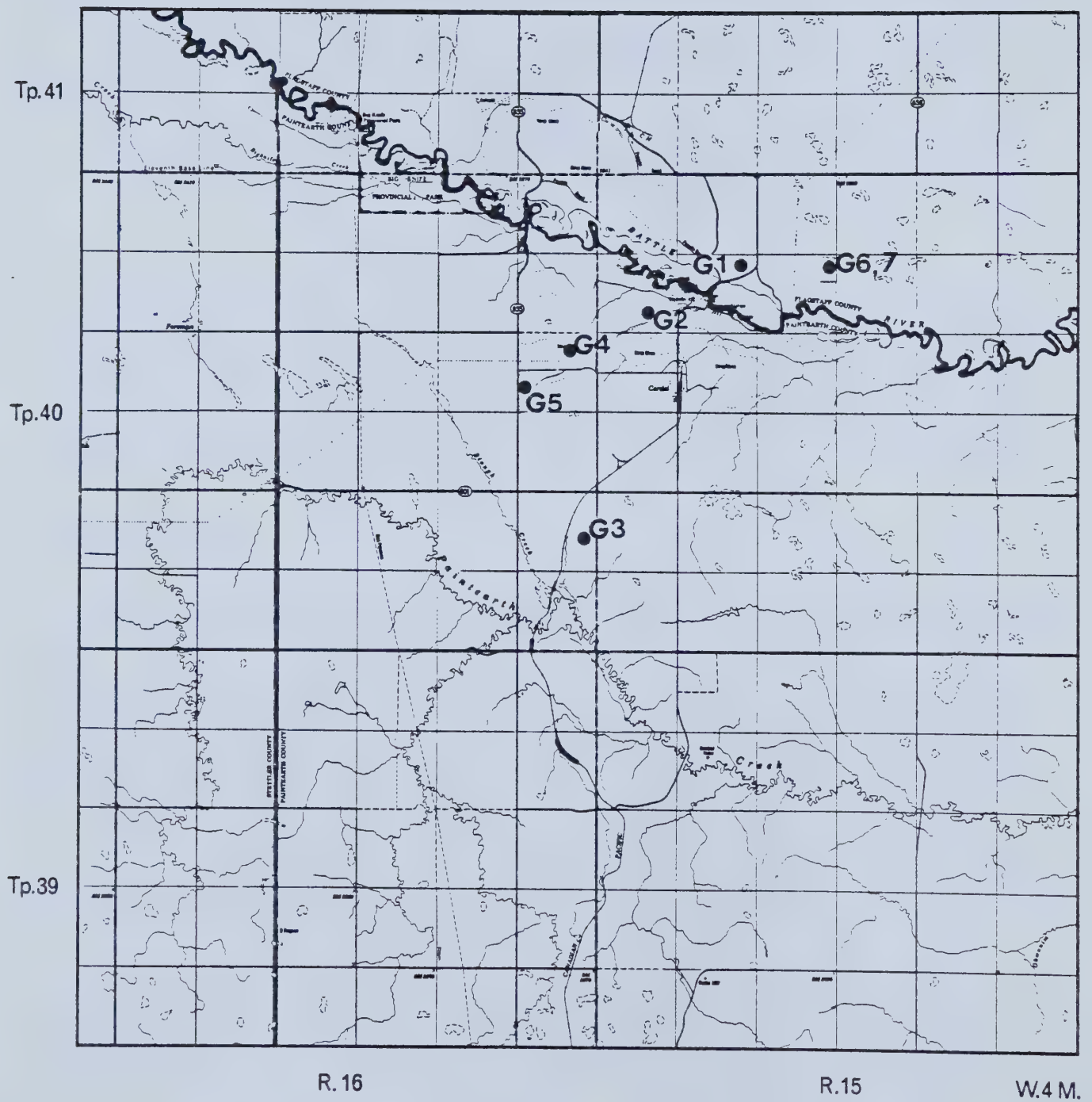


Figure 2. Location of field sites for gas sampling.

Lab Operations

The laboratory procedures are geared to preparing samples for standard gas analysis and for purifying CO_2 samples for determination of the C-13/C-12 ratio by mass spectrometry. The gas sample was expanded into a 100 mL bulb for determination of mole percent oxygen, nitrogen, carbon dioxide, and sulfur dioxide. A custom-built thermo-conductivity gas chromatograph (g.c.) was used to analyze for CO , O_2 , N_2 , CH_4 and CO_2 . The sensitivity of the instrument was such that less than 0.005% of O_2 , N_2 , and CO_2 could be detected¹. Carbon dioxide was removed from the remaining gas by cooling with liquid nitrogen. Uncondensable gases such as oxygen, nitrogen, and argon were pumped off, and traces of water were removed from the sample by allowing the frozen CO_2 to sublime from a dry-ice alcohol slush trap. The purified CO_2 was sealed into a glass ampule which could be placed directly in the mass spectrometer at the stable isotope laboratory of Prof. H. R. Krouse, University of Calgary.

RESULTS

The dates of sampling as well as the depths of the various gas samplers are given in Table 1. The results of the gas analyses are portrayed graphically, where the abscissa indicates various sequential samplings during the 1981 and 1982 field seasons.

Natural Setting, Bluff on Battle R. North (BRG1)

Figure 4a shows the trend of CO_2 levels in this control setting. The curves for the shallow and intermediate samples, A and B, show stable values for the monitoring interval, while curve C rose and stabilized at a value higher than the initial level. In this hole, the level of CO_2 increases with depth.

The oxygen levels shown on figure 4b are the inverse of the former. It is interesting to note the significant drop in oxygen level at depths B and C over the first field season. It appears that oxygen was introduced to the unsaturated zone at depths of 7.7 and 12.6 metres over the winter. Oxygen levels are much more variable than those for CO_2 .

Natural Setting Bluff on Battle R. South (BRG2)

Figure 5a shows CO_2 levels increasing gradually at all depths during the monitoring period. There does not appear to be a regular increase of CO_2 with depth at this site. The very low CO_2 levels in B and C initially suggest that a long time was required to purge the contaminating effect of the instrument installation at this site.

The oxygen curves shown in figure 5b show a drop in oxygen level for curves C and B, but an increase for the shallow sample A. Initially, the oxygen level increased with depth; however, at the last sampling the situation had practically reversed, with the shallow sample bearing the highest level of oxygen.

¹ Gas chromatography done by Chemex Labs, Calgary

TABLE 1. Depths of Samples and Dates of Sampling

Site	Depth (Meters)	Dates of Sampling		Setting
BRG1A	3.3	81-09-02	81-10-01	North bluff of Battle, River Natural Setting
BRG1B	7.7	82-06-17	82-07-19	
BRG1C	12.6	82-09-09		
BRG2A	5.0	81-09-02	81-10-01	South bluff of Battle River Natural Setting
BRG2B	8.9	82-06-17	82-07-19	
BRG2C	13.6	82-09-09		
BRG3A	2.4	81-10-01	81-11-17	North bluff of Paintearth Creek, Natural Setting
BRG3B	4.7	82-07-19	82-09-09	
BRG3C	8.9			
BRG3D	12.1			
BRG4A	3.8	81-09-02	81-10-01	Vesta Mine Reclaimed Spoil
BRG4B	6.8	82-06-25	82-07-19	
BRG4C	12.0	82-09-09		
BRG6A	1.2	81-09-02	81-10-01	Diplomat Mine Reclaimed Spoil
BRG6B	3.0	82-06-17	82-07-20	
BRG6C	4.4	82-09-09		

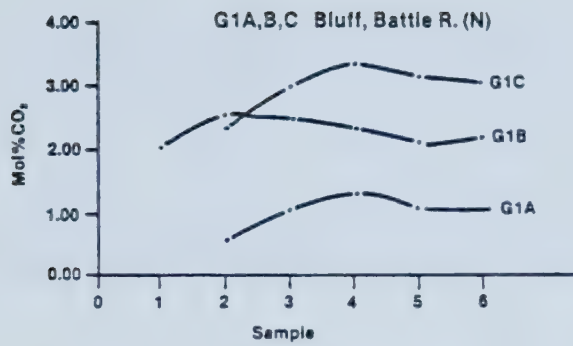


Figure 4a. G1-CO₂

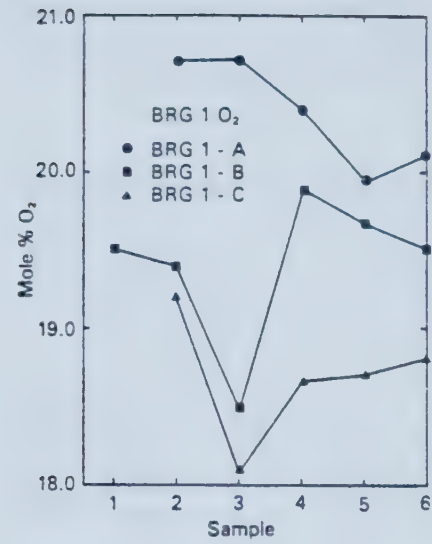


Figure 4b. G1-O₂

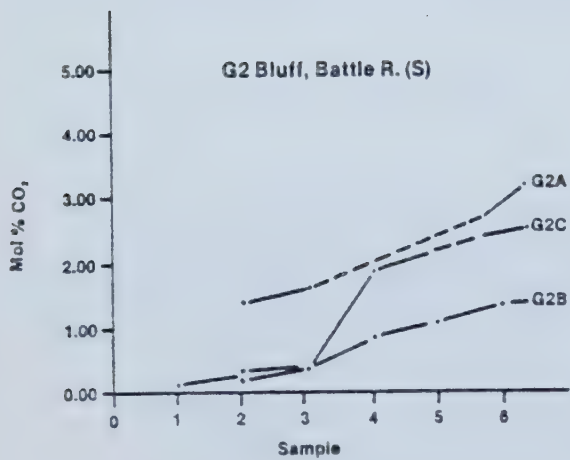


Figure 5a. G2-CO₂

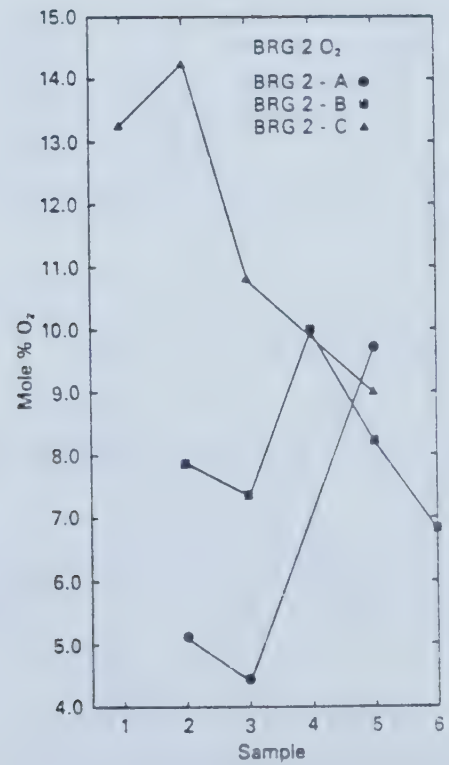


Figure 5b. G2-O₂

Natural Setting, Bluff overlooking Paintearth Creek (BRG3)

The CO₂ levels for this site are given on Figure 6a. A much larger range of values occurred at this site than the other two control sites, i.e. 1 - 13% vs about 1 - 3%. The highest CO₂ levels occur at shallow depth.

Oxygen levels were generally higher with increasing depth, as shown in figure 6b. The initial condition in order of increasing oxygen level was B C A D. After significant fluctuation at the second sampling, the same B C A D sequence was found.

Discussion of the Control Data

With the exception of G1, the gas composition in the unsaturated zone is not constant for the natural settings. The variations in oxygen level and the presence of high oxygen levels at depths in excess of 12 metres suggest that the unsaturated zones are open systems with respect to the atmosphere.

It is interesting to compare the final oxygen and CO₂ levels for the deepest sample at each of the three control sites (the deepest samples come from a restricted depth range of 12.1 - 13.6 metres) in order to test the similarity of the control sites, viz:

	O ₂ (%)	CO ₂ (%)
G1C	18.8	3.1
G2C	9.0	2.5
G3D	19	1.0

Apparently, the CO₂ levels at various depths are similar. These levels are approximately 100 x higher than for normal air (.03%). The equilibrium partial pressure of CO₂ calculated for groundwater from drift aquifers in east central Alberta is approximately 10⁻² atm. (Wallick, 1981). If PCO₂ for normal air is 10^{-3.5} atm, and the values measured in the unsaturated zone are 100 x higher, we have reason to believe that the observed 10^{-1.5} atm PCO₂ for the deepest part of the unsaturated zone is the background CO₂ partial pressure.

The level of oxygen does not seem to stabilize in the unsaturated zone. Therefore its use as a reference for comparison in the disturbed settings is uncertain at this time.

Reclaimed Spoil, Vesta Mine, North (BRG4)

The CO₂ levels and oxygen levels (Figs. 7a, b) are relatively low and constant. CO₂ levels are at background, according to the above criteria. Oxygen levels are slightly depressed from the atmospheric norm of 21%. In general the curves for this reclaimed site are identical to the control setting BRG1.

Reclaimed Spoil, Diplomat Mine, East (BRG6)

This site had the highest CO₂ levels recorded and the corresponding

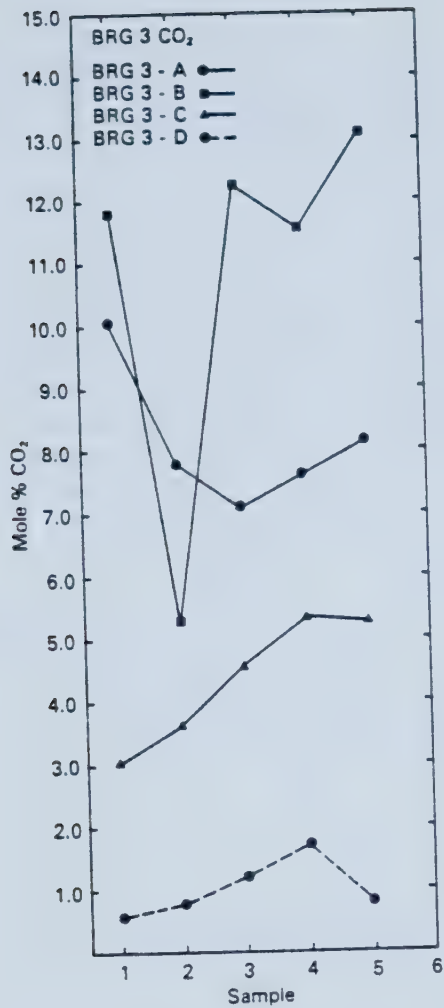


Figure 6a. G3-CO₂

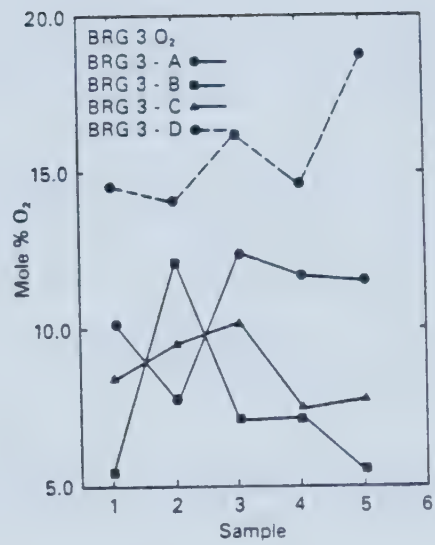


Figure 6b. G3-O₂

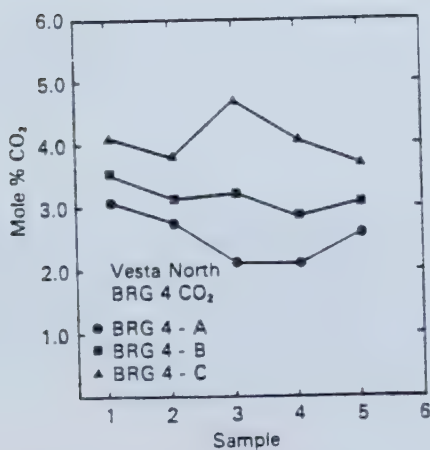


Figure 7a. G4-CO₂

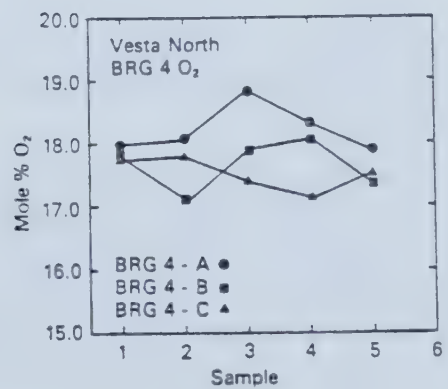


Figure 7b. G4-O₂

lowest oxygen level. Figure 8a shows that CO₂ levels rose and then fell during the 1981 monitoring. The CO₂ values reached are about 1000 x higher than for normal air. Over the winter, a major release of CO₂ from the system resulted in background values for G6A, B. However, G6C climbed back to 14 mole % CO₂ during the 1982 monitoring season.

The oxygen curves in figure 8b showed that the thickness of the unsaturated zone that was described by G6a, B (1.2 - 3.0 metres) was opened to the atmosphere over the winter of 1981-82. Oxygen was apparently consumed at the depth of 4.4 metres as shown by the drop in oxygen level of curve C.

Discussion of Reclaimed Spoil Data

On the basis of the CO₂ and O₂ curves above, it is clear that the reclaimed spoil at Vesta Mine North has reached a state of geochemical equilibrium while the reclaimed spoil at the Diplomat Mine, East has not. This does not necessarily imply that chemical reactions at Vesta Mine North have ceased - only that the rates at which gases are produced and consumed have equalized. However, the fact that the CO₂ and O₂ levels are the same as the control BRG1 levels support to the conclusion that background values have been attained.

The high levels of CO₂ at Diplomat Mine, East are a curious phenomenon. Several questions emerge as to the source of the CO₂, the nature of the chemical reactions that are taking place to produce the CO₂, and whether the reactions are the same in natural as well as reclaimed settings.

Carbon Isotopy of CO₂

Analysis of the ratio of carbon -13 to carbon -12 in CO₂ from the unsaturated zone was performed to determine the source and production mechanism of CO₂ at different sites in the mine area.

In order to understand the data shown on Figure 9, consider the definition of the "del" notation:

$$\text{del C-13} = \left[\frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}} - 1}{(^{13}\text{C}/^{12}\text{C})_{\text{standard}}} \right] \times 1000$$

The standard for carbon isotope measurements is PDB, a calcite rostrum from Belemnitella americana, a fossil collected from the Cretaceous Pee Dee Formation in South Carolina. All del values are expressed in parts per thousand (‰).

Figure 9 shows that CO₂ from natural and reclaimed areas has a distinct carbon isotope composition. The lack of overlap between the three groups of samples signifies that differentiation is possible not only between natural and disturbed environments but also between one disturbed environment and another. It is interesting to recall how variable the gas composition was for each site and yet the values of del C-13 are tightly grouped.

Shown on the right half of figure 9 is the range of CO_2 levels found for each of the field situations: natural, undisturbed settings, and the Vesta and Diplomat reclaimed areas. The three settings have different ranges of CO_2 levels, with by far the highest values occurring at the Diplomat Mine.

Discussion

In nature, $\delta\text{C-13}$ for organic carbon ranges between -21 and -27‰ PDB, whereas marine carbonates have values of $\delta\text{C-13} \sim 0\text{‰}$. The $\delta\text{C-13}$ values for the natural settings fall into the range of organic carbon, suggesting that oxidation of organic carbon is the likely source of the CO_2 . (Any suspicion that the CO_2 is atmospheric contamination can be ruled out because all of the $\delta\text{C-13}$ values observed were significantly lighter than -7‰ PDB, the value for atmospheric carbon dioxide. Furthermore, the normal level of CO_2 in the atmosphere is 0.03 mole %, a factor of 10-30 less than the lower limits observed.) The isotopically heavy values for CO_2 from the Diplomat Mine are most likely caused by oxidation of organic carbon to yield isotopically "light" CO_2 , mixing with CO_2 produced by reaction of sulfuric acid with marine limestone/dolostone which is isotopically "heavy". This mechanism would account for the observation that the $\delta\text{C-13}$ values from the Diplomat Mine are halfway between the organic carbon and marine carbonate means while the levels of CO_2 observed at the Diplomat Mine were as high as double the natural values.

Sources and Reaction Mechanism for CO_2

The isotopic data clearly indicate that two sources exist that yield CO_2 : organic carbon and marine carbonate. The following reactions are therefore likely in the unsaturated zone.

- a. $\text{C}_{\text{org}} + \text{O}_2 \rightarrow \text{CO}_2 \uparrow$
- b. $\text{S}_{\text{pyrite/org}} + \text{O}_2 \rightarrow \text{SO}_2$
- c. $\text{SO}_2 + \text{H}_2\text{O} + \frac{1}{2} \text{O}_2 \rightarrow \text{H}_2\text{SO}_4$
- d. $\text{H}_2\text{SO}_4 + \begin{bmatrix} \text{CaCO}_3 \\ \text{CaMg}(\text{CO}_3)_2 \end{bmatrix} \rightarrow \begin{bmatrix} \text{CaSO}_4 \\ \text{MgSO}_4 \end{bmatrix} + \text{H}_2\text{O} = \text{CO}_2 \uparrow$

If relatively equal volumes of CO_2 are produced by reactions a. and d. above, the isotopic composition should be about half way between the average value for organic carbon and marine carbonate, or $\delta\text{C-13} = (24 + 0)/2 = 12.5\text{‰}$. This is the approximate value that was observed for Diplomat East.

It is interesting to note that the overburden at Diplomat East consists mainly of till that contains a high content of marine carbonate. Mixture of this overburden with organic rich shale and coal fragments during mining will produce a spoil environment that promotes reactions of the kind written above. Authigenic gypsum has been observed in the spoil material, lending further support to the reaction of type d.

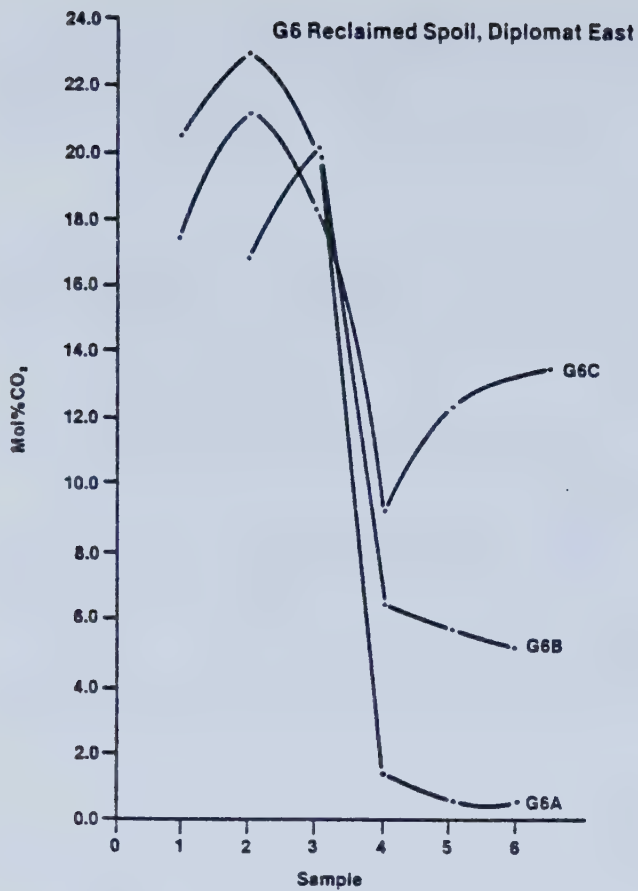


Figure 8a. G6-CO₂

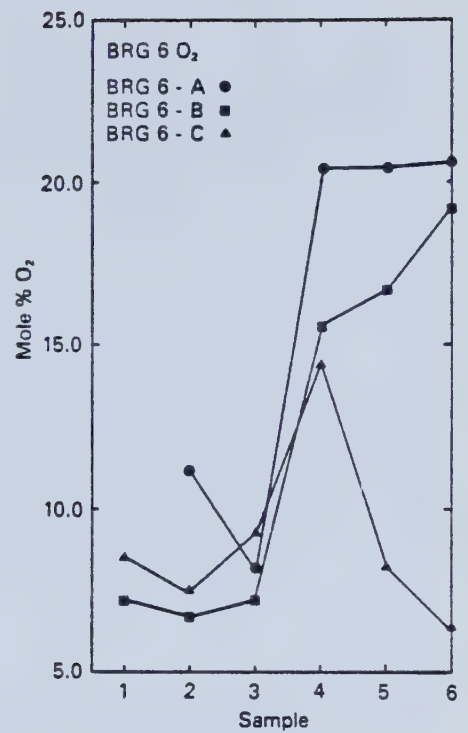


Figure 8b. G6-O₂

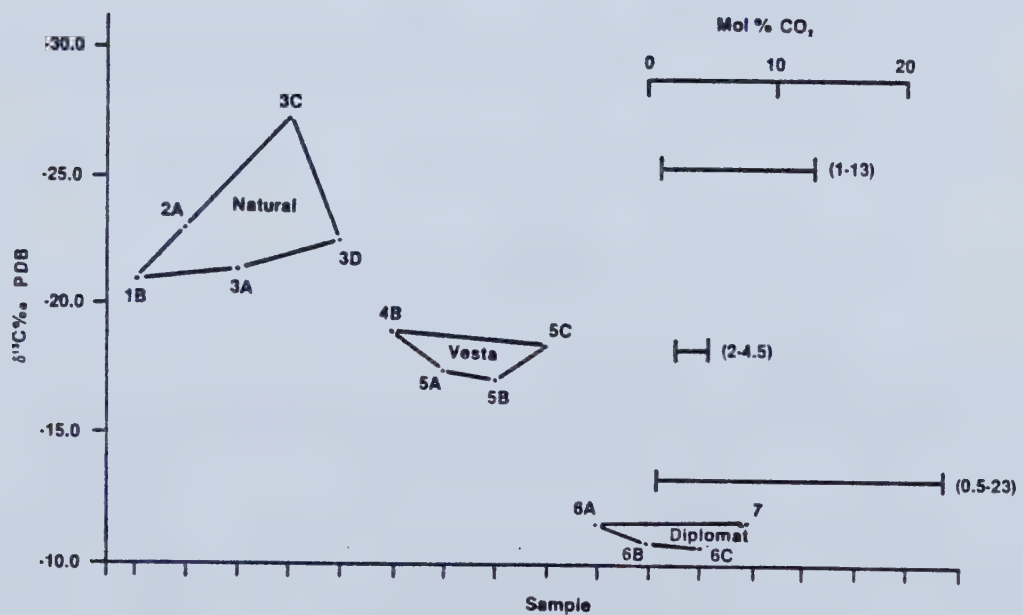


Figure 9. $\delta^{13}\text{C}$ in CO₂.

SUMMARY AND CONCLUSIONS

Based upon two years of monitoring of the gas composition of the unsaturated zone at several undisturbed sites and two mined and reclaimed sites, it can be concluded that the progress toward a new stable landscape is reflected by trends in the gas composition. The level of CO_2 is particularly sensitive to land disturbance and the isotopic composition of the CO_2 ($^{13}\text{C}/^{12}\text{C}$) reflects both the source and mechanism of production of the CO_2 . The isotopic compositions of CO_2 from various settings in the Battle River mine area were sufficiently different to indicate that considerable variation in carbon sources in the unsaturated zone are to be expected even within a relatively small area.

REFERENCE

Wallick, E.I., 1981, Chemical evolution of groundwater in a drainage basin of Holocene age, east-central Alberta, Canada, J. Hydrol., v. 54, pp. 245-284.

ACKNOWLEDGMENTS

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PREDICTION OF GROUNDWATER CHEMISTRY
IN RECLAIMED LANDSCAPES

By

M. Trudell, A. Maslowski, E. Wallick and S.R. Moran¹

ABSTRACT

The determination of salt-yielding properties of surface-mine overburden has been undertaken as an approach to predicting the chemistry of groundwater in mine spoil. Saturation extract analyses of overburden samples are limited by mineral saturation constraints. The first leach of an infinite dilution type experiment (10:1 water to sediment) provided the best approximation of spoil groundwater composition, although it produced insufficient sulfate. All of the methods studied overestimated the salinity of spoil groundwater.

Salt yields from drift provide the best approximation of spoil groundwater composition, whereas bedrock samples produced too little sulfate, calcium and magnesium. The composition of the spoil groundwater appears to be determined mainly by thin layers of highly saline drift or weathered bedrock, although the salinity of the spoil groundwater depends on the access of water to the salts within the spoil, and on mineral solubility.

This work was carried out as part of the Plains Hydrology and Reclamation Project, which is supported by the Alberta Heritage Savings Trust Fund and administered by the Reclamation Research Technical Advisory Committee (R.R.T.A.C.) of the Alberta Land Conservation and Reclamation Council.

INTRODUCTION

One of the important environmental impacts of surface mining of coal is the potential alteration of quality of groundwater in and adjacent to mined areas. In order to make planning decisions we would like to be able to predict post-mining water chemistry on the basis of data from the pre-mining setting. Two obvious approaches suggest themselves. The first is to use the chemistry of water in wells already in the area prior to mining. The second is to use the chemistry of a water extract of the overburden materials that will make up the backfill material in the mined area.

The first approach has the advantage of being easy and cheap to obtain. In many sites, enough analyses from existing wells are already available to allow an overview of the pre-mining water chemistry.

¹Research Officers, Alberta Research Council, Edmonton, Alberta

Installation and sampling of a small number of additional wells generally can complete the picture. The problem however is that the chemistry of pre-mining groundwater bears little resemblance to the chemistry that develops in mine spoil. The chemistry of water in mine spoil in Alberta, North Dakota (Williams, and others, in press) and Montana (Van Voast, in press; Van Voast, 1982) is almost everywhere significantly more saline than in pre-mining aquifers. In addition, the relative abundance of ions commonly shifts significantly, with sodium and sulfate most commonly being considerably more dominant in groundwater in spoil. Limited data on groundwater from fine-grained confining beds in the overburden suggest that the chemistry in these beds may better approximate that in mine spoil both in composition and salinity. However, pre-existing water wells do not sample these units because of their low yield and proper construction and sampling of wells in such materials is a slow and difficult process.

The use of an aqueous extract from overburden materials is generally considered to provide the best approach to predicting post-mining chemistry. The most commonly available extract data is the saturated paste extract that is almost universally used for overburden suitability assessment in reclamation. Simply by adding one or two anions to the standard saturation extract analysis, a data base is generated that can be related to groundwater chemistry. Van Voast working in Montana, reported that compositions of saturation extracts provided a suitable approximation of post-mining water chemistry (Van Voast, in press). In the remainder of this paper we examine the applicability of the saturation extract to prediction of groundwater chemistry in mine spoil in central Alberta. A second type of extract, that of about a 10:1 (water:sediment) and a 40:1 exhaustive leach, is also examined. Our conclusion is that the 10:1 leach extract approximates the ionic composition of the post-mining groundwater better than the saturation extract but that neither provides a very good approximation of salinity.

ESTIMATION OF IONIC COMPOSITION OF POST-MINING GROUNDWATER

The approach that we have taken to this problem is to convert the concentration of salt from the extract data to a yield of salt in g/kg of solid material. The various materials in the overburden are then conceptually mixed to produce a composite overburden sample for the domain under consideration. Finally the appropriate amount of water is added to the solid material and the resulting concentration of salt is calculated. This projected spoil groundwater chemical composition has then been compared with known values from adjacent mined areas to evaluate how well the projection matches the observed reality.

The initial trial of this method involves an area of instrumented mine spoil in the southwest corner of the Vesta Mine in SW $\frac{1}{4}$ 24-40-16W4 and a core hole located just south of the Highwall in SW $\frac{1}{4}$ 2-24-40-16W4 (Figures 1,2).

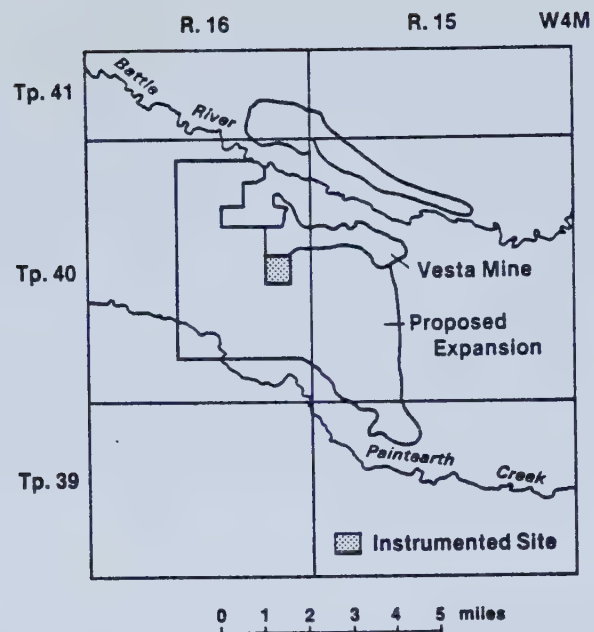


Figure 1. Location of study area.

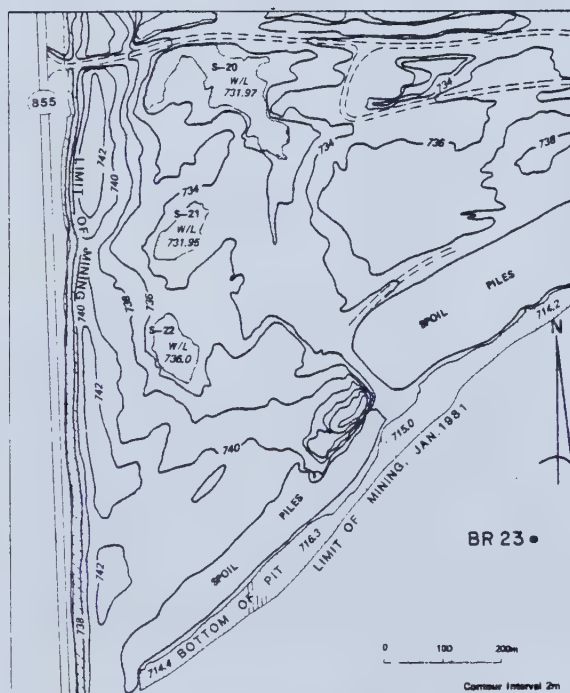


Figure 2. Detailed location map, Vesta Mine and testhole BR-23.

APPLICATION OF SATURATION EXTRACT DATA FOR PREDICTION OF IONIC COMPOSITION

The concentration data obtained from a saturation extract analysis can not be directly compared because of the differing water content of various samples. The first step in using these data is therefore to standardize the data by converting to salt yield in g/kg. Each ion is converted to concentrations in mg/l then multiplied by the saturation percentage expressed as a decimal fraction and divided by 1000 to give the yield in g/kg (Table 1).

The next step is to calculate a salt yield for the entire borehole. The only systematic compositional distinction between overburden materials that we have been able to discover is that between the bedrock of the Horseshoe Canyon Formation and the overlying glacial drift. We have examined 155 analyses from our own core holes plus another several hundred from samples collected by Alberta Environment, Manalta Coal Co. and Luscar Ltd. We have been unable to detect any lithologic or stratigraphic control on overburden composition within the Horseshoe Canyon Formation. Therefore we have used the approach of combining all samples of the bedrock into a single mixed value, the arithmetic mean (Table 1). A similar single value for the drift has been calculated (Table 1). These two values are then weighted on the basis of the relative thickness of the two materials in the borehole and a single composite overburden composition for that borehole has been calculated. Comparison of these data from BR-23, which are plotted in Figure 3, with the analyses of groundwater in spoil in the adjacent Vesta mine clearly show very poor correlation. The saturation extract values significantly under represent the divalent cations, calcium and magnesium, and sulfate (Figure 3). This same pattern has been observed with all the saturation extract values that we have examined.

APPLICATION OF EXHAUSTIVE LEACH DATA TO PREDICTION OF IONIC COMPOSITION

This leaching procedure, termed "infinite dilution", was developed to determine the ultimate salt yield of overburden materials. The procedure involves placing 5 gm of ground sample in a flask with 50 ml of distilled water and agitating for 0.5 hour. After centrifuging the clear water is withdrawn, distilled water is added back to 50 ml and the process is repeated. From 7 to 10 cycles have been run for the materials tested.

Examination of the data reveals significant changes in sample behaviour after the third or fourth leach. It appears that prior to that point the salt produced consists of leachable ions; after that point silicate breakdown begins and further release of ions involves destruction of mineral structure. We have examined the first and fourth leach as possible predictors of spoil water chemistry.

Of the infinite dilution leaches, the first test best approximates the composition of spoil groundwater (Table 2, Figure 4). The overall composition of this first leach for site BR-23 has a calcium and magnesium

	SAMPLE NO.	Na	K	Ca	Mg	SO ₄	HCO ₃	Cl	TDS
Glacial Drift	1	1.046	0.035	0.142	0.067	1.828	1.268	0.007	4.394
	2	1.060	0.028	0.074	0.022	1.452	1.329	0.011	3.975
Horseshoe Canyon Formation	3	0.515	0.046	0.004	0.003	0.640	0.602	0.030	1.841
	4	0.617	0.020	0.004	0.002	0.424	1.102	0.028	2.197
	5	2.095	0.060	0.107	0.012	2.289	3.101	0.017	7.682
	6	0.272	0.065	0.003	0.001	0.136	0.638	0.015	1.130
	7	0.651	0.048	0.006	0.002	0.693	0.918	0.019	2.338
	9	0.712	0.044	0.005	0.002	0.174	1.709	0.032	2.677
Mean Values	$\bar{X}$	1.053	0.032	0.108	0.044	1.640	1.299	0.009	4.184
Glacial Drift	σ	(0.010)	(0.005)	(0.048)	(0.032)	(0.266)	(0.043)	(0.003)	(0.296)
Mean Values Horseshoe Canyon Formation	$\bar{X}$	0.810	0.047	0.022	0.004	0.726	1.345	0.024	2.978
	σ	(0.648)	(0.016)	(0.042)	(0.004)	(0.799)	(0.950)	(0.007)	(2.364)
Composite for BR-23		0.887	0.042	0.050	0.017	1.019	1.330	0.019	3.364

Table 1. Salt yield in g/kg for overburden from testhole BR-23 determined by saturated paste extract. Composite value determined on the basis of mean weighted by relative thickness of drift (0.3204) and rock (0.6796).

SAMPLE NO.	Na	K	Ca	Mg	SO ₄	HCO ₃	Cl	TDS
Glacial Drift								
1A	1.116	0.049	0.010	0.004	2.138	0.239	0.013	3.569
1B	1.924	0.086	0.870	0.684	9.731	0.285	0.019	13.596
2	1.404	0.049	0.012	0.007	2.386	0.890	0.011	4.761
Horseshoe Canyon Formation								
3	1.261	0.022	0.041	0.065	0.677	1.662	0.007	3.736
4	1.102	0.039	0.060	0.171	0.225	2.516	0.003	4.114
5	1.071	0.014	0.013	0.003	0.189	1.871	0.013	3.175
6	1.035	0.026	0.011	0.003	0.183	2.277	0.010	3.547
7	0.907	0.043	0.012	0.005	0.837	0.946	0.014	2.763
8	1.481	0.063	0.070	0.010	0.967	1.977	0.030	4.599
9A	0.771	0.010	0.013	0.003	0.142	1.266	0.015	2.222
9B	1.004	0.026	0.052	0.196	0.257	2.725	0.015	4.286
10	1.326	0.047	0.019	0.007	0.304	2.511	0.010	4.227
Mean Values								
Glacial Drift	1.481	0.061	0.297	0.232	4.752	0.471	0.014	7.309
n = 3	(0.410)	(0.021)	(0.496)	(0.392)	(4.314)	(0.363)	(0.004)	(5.478)
Mean Values Horseshoe Canyon Formation	1.106	0.032	0.032	0.051	0.420	1.972	0.013	3.630
n = 9	(0.218)	(0.017)	(0.024)	(0.078)	(0.317)	(0.602)	(0.008)	(0.784)
Composite for BR-23	1.226	0.041	0.117	0.109	1.808	1.491	0.013	4.809

Table 2. Salt yield in g/kg for overburden from testhole BR-23 determined from the first infinite dilution leach. Composite value determined on the basis of mean weighted by relative thickness of drift (0.3204) and rock (0.6796).

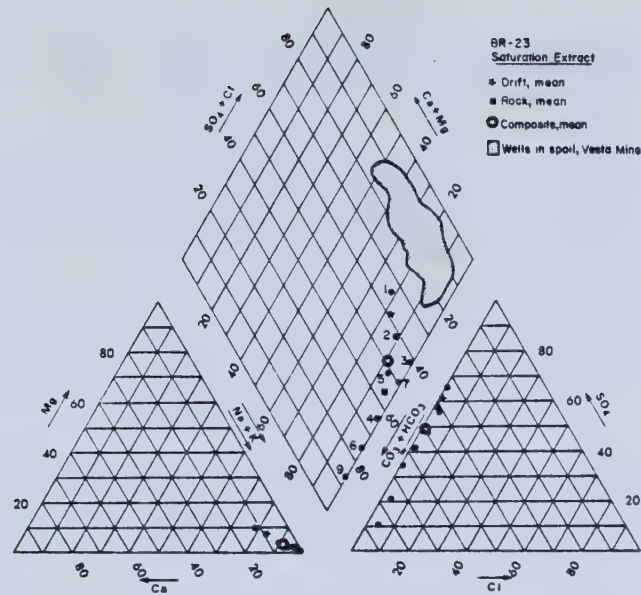


Figure 3. Composition of salts from saturation extracts; samples from testhole BR-23.

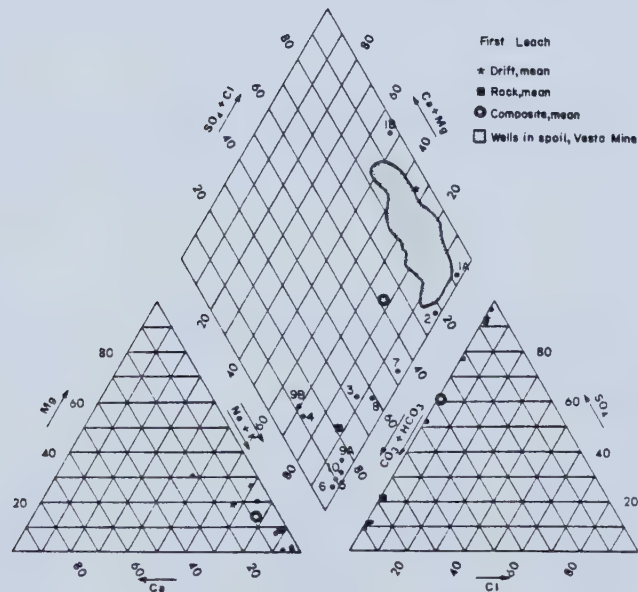


Figure 4. Composition of salts after first infinite dilution leach; samples from testhole BR-23.

composition that is consistent with that in spoil groundwater and a relative abundance of sulfate only about 15% lower than the spoil water samples.

The predicted groundwater composition from the fourth infinite dilution leach better approximates the observed water chemistry in the spoil at Vesta Mine (Table 3, Figure 5) than does the saturated extract. The calcium and magnesium content is much the same as many of the spoil water samples, but the relative abundance of sulfate is the same as in the saturation extract, at least 25% lower than in the spoil water samples.

DISCUSSIONS

Examination of Figures 3, 4, and 5 leads to a number of interesting observations.

The first infinite dilution leach from site BR-23 best approximates the composition of groundwater in mine spoil. Both the saturation extract and the fourth infinite dilution leach contain relatively too little sulfate and the saturation extract is deficient in calcium and magnesium. However none of these composites of data from BR-23 does a very good approximation of the spoil groundwater.

We have long considered that one of the problems in assessing salt yield of overburden materials by means of the saturated paste extract method is that chemical saturation constraints likely limit the solubility of certain minerals. This effect should be particularly important for calcite and dolomite. A plot of the data for saturated paste and a series of infinite dilution leaches for various types of overburden suggests that in fact the abundance of all of the major ions is solubility limited in the former (Figures 6-9). Calculations using WATEQF confirm that the paste extracts are saturated to supersaturated with respect to calcite and dolomite. Sample 24-1A (Figure 6) represents a highly saline calcium-sulfate producing drift sample showing strong mineral saturation control on all species from the saturation extract test. Sample 5-1 (Figure 7) is a shallow bedrock overburden sample that produces sodium-bicarbonate-sulfate of moderate salinity, and displays significant saturation control on calcium and bicarbonate, with minor control on other species. The deeper bedrock overburden represented by sample 5-8 (Figure 8) produces sodium-bicarbonate, and shows strong saturation control on calcium and magnesium. For each of these species the saturation extract values are more than an order of magnitude less than in subsequent infinite dilution tests. Saturation control on other species from this moderately saline sample is minor; the declining chloride is probably due to analytical error or sample inhomogeneity. Sample 23-6 is another moderately saline bedrock overburden sample that produces sodium-bicarbonate but in this case sodium is inhibited as well as calcium and magnesium, each of which is three to four times lower in the saturation extract than the infinite dilution test. Bicarbonate is also suppressed, while control on sulfate is minor. Decline in

	SAMPLE NO.	Na	K	Ca	Mg	SO ₄	HCO ₃	Cl	TDS
Glacial Drift	1A	1.28	0.23	0.03	0.02	2.03	0.36	0.05	3.98
	1B	2.02	0.12	1.21	0.72	9.77	0.87	0.04	14.73
	2	1.70	0.13	0.04	0.02	2.38	2.25	0.03	6.58
Horseshoe Canyon Formation	3	2.24	0.06	0.10	0.12	0.74	4.39	0.03	7.66
	4	1.83	0.07	0.10	0.22	0.23	4.23	0.01	6.68
	5	2.03	0.04	0.04	0.01	0.18	3.78	0.03	6.09
	6	1.55	0.04	0.04	0.01	0.21	3.23	0.02	5.08
	7	1.26	0.10	0.03	0.01	0.85	1.46	0.02	3.71
	8	2.03	0.11	0.10	0.02	0.98	3.10	0.06	6.39
	9A	1.13	0.02	0.40	0.01	0.17	1.80	0.03	3.19
	9B	1.84	0.05	0.12	0.24	0.24	5.33	0.02	7.85
	10	1.95	0.08	0.04	0.01	0.30	3.68	0.02	6.07
	$\bar{X}$	3.15	0.31	1.06	1.75	2.01	0.32	0.04	8.430
Mean Values Glacial Drift n = 3	σ	(0.71)	(0.04)	(1.69)	(2.80)	(1.86)	(0.27)	(0.02)	(5.609)
Mean Values Horseshoe Canyon Formation n = 9	$\bar{X}$	3.33	0.04	0.17	0.05	0.43	3.44	0.02	5.858
	σ	(0.71)	(0.02)	(0.09)	(0.07)	(0.33)	(1.23)	(0.01)	(1.605)
Composite for BR-23		3.272	0.127	0.455	0.595	0.936	2.440	0.026	6.682

Table 3. Salt yield in g/kg for overburden from testhole BR-23 determined from the fourth infinite dilution leach. Composite value determined on the basis of mean weighted by relative thickness of drift (0.3204) and rock (0.6796).

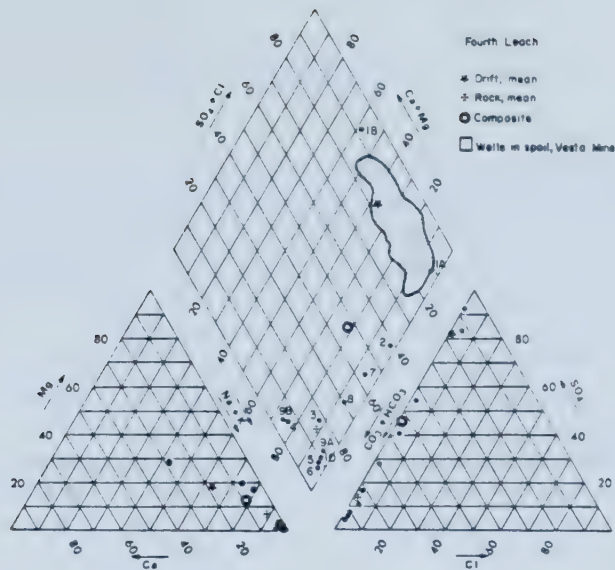


Figure 5. Composition of salts after fourth infinite dilution leach; samples from testhole BR-23.

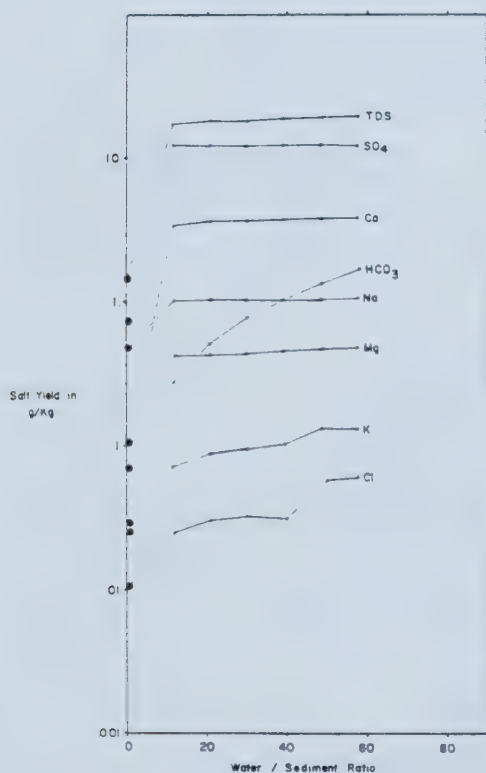


Figure 6. Salt production from saturation extract (large dots) and infinite dilution tests (small dots) for sample 24-1A (glacial drift).

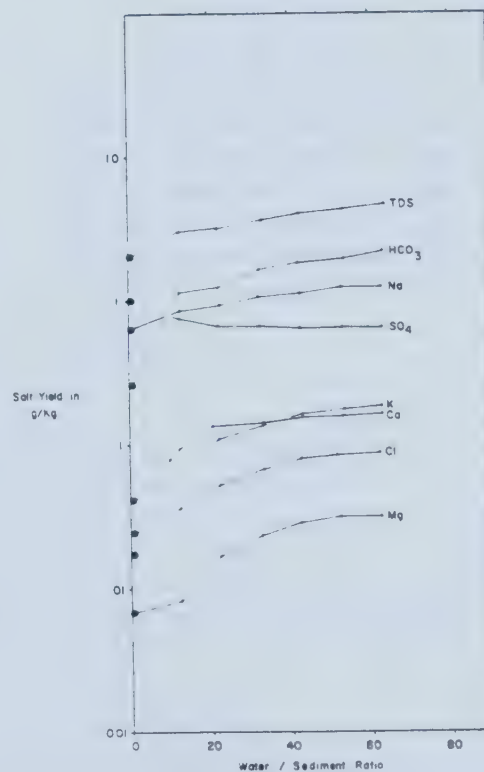


Figure 7. Salt production from saturation extract (large dots) and infinite dilution tests (small dots) for sample 5-1 (bedrock overburden).

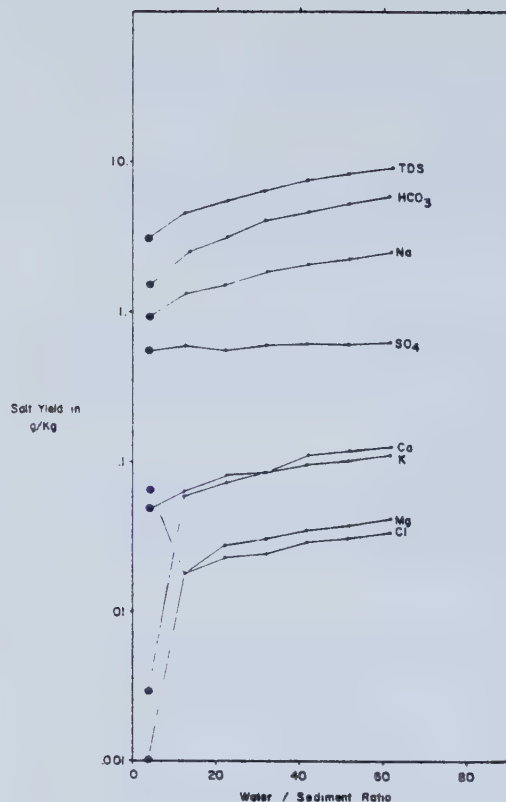


Figure 8. Salt production from saturation extract (large dots) and infinite dilution tests (small dots) for sample 5-8 (bedrock overburden).

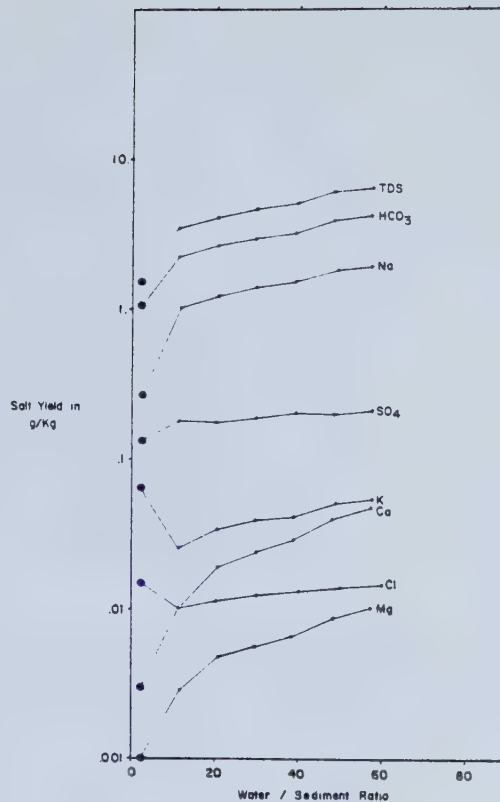


Figure 9. Salt production from saturation extract (large dots) and infinite dilution tests (small dots) for sample 23-6 (bedrock overburden).

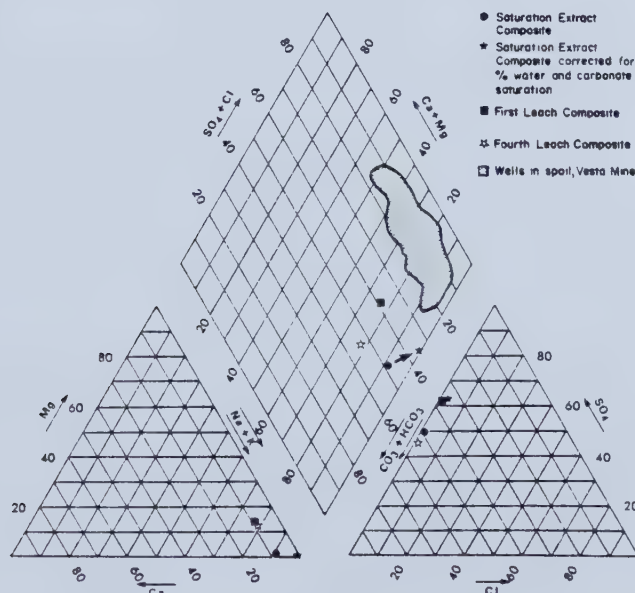


Figure 10. Summary of salt composition of composite samples, testhole BR-23. Arrow indicates composition shift caused by carbonate mineral saturation.

chloride and potassium yields are probably a reflection of sample inhomogeneity.

To evaluate the effect of this chemical saturation phenomenon on the relative abundance of sulfate and bicarbonate in the extract, we have recalculated the composite composition at the field moisture content. Our data show that the mean porosity of spoil in Vesta Mine is about 30%. Assuming that the spoil is saturated, this gives a water content of about 16.5% by weight. The paste extract data have been recalculated to this water content by concentrating the salt and removing sufficient calcium, magnesium and bicarbonate to maintain saturation with respect to calcite and dolomite. The resulting composition (Figure 10) is somewhat improved as a predictor of the composition of spoil water with respect to the sulfate to bicarbonate but it is made worse with respect to the amount of calcium and magnesium.

In none of the extracts does the water derived from the bedrock bear any resemblance to the spoil groundwater. The relative abundance of sodium and bicarbonate is far too high in all the samples. The ionic composition of the water from the drift on the other hand lies within the range of values found in the spoil groundwater. From these two observations we conclude that the chemistry of groundwater currently in spoil at the Vesta Mine has been strongly controlled by glacial drift in the overburden and to only a very limited extent by the bedrock.

The instrumented site lies in an area of older mining where, to our knowledge, little salvage of overburden materials was practiced. Therefore, we consider it likely that the glacial drift material that lay just beneath the surface in the pre-mining landscape now occupies the base of the spoil. From this, one could conclude that selective placement of the glacial drift and weathered bedrock back at the top of the spoil, where it would likely remain unsaturated, could materially influence the chemistry of groundwater in the spoil. Alternatively it has been suggested that the bulk of the chemical characteristics of groundwater are acquired in transit through the unsaturated zone (Moran, and others, 1978). Following this reasoning, the chemical composition of groundwater in Vesta Mine spoil would have formed passing through the drift material that has been placed on the surface in the instrumented area. We are inclined to favour the former interpretation but further work is needed to verify that the second process is not important.

A third significant observation is the importance of small amounts of highly saline overburden in controlling the composite composition of the resulting mix. One sample, sample 1B, is almost entirely responsible for the higher salinity, calcium and magnesium content of the drift in both the first and fourth infinite dilution leaches. One implication of this is that a zone containing a high concentration of secondary salt or oxidizable pyrite need not be very thick to have a significant impact on the overall composition of the resulting groundwater. A second implication is that prediction of spoil water composition is made

more difficult because of the need to sample thin or laterally inextensive critical zones rather than to determine overall bulk characteristics of the overburden.

PROJECTION OF SALINITY OF POST-MINING GROUNDWATER

The approach that we have taken to this process is to determine the total salt yield per kg and then, using a reasonable saturated porosity, calculate the resulting TDS of the water in contact with the overburden.

As indicated above, the porosity of spoil at Vesta Mine is about 30% and we have used this value in the calculations that follow. On the basis of corrected gamma ray density log characteristics, we have used the mean density of above 2.0 g/cm³ for the unmined overburden. The TDS of the overburden composite for the three extracts under consideration is 3.365 g/kg (saturated paste), 4.809 g/kg (first infinite dilution leach), and 6.682 g/kg (fourth infinite dilution leach). These salt yields result in salinity of groundwater of 22,435 mg/l, 32,060 mg/l, and 44,545 mg/l respectively at 30% porosity. The mean salinity of groundwater in 24 samples from spoil at Vesta Mine is about 7425 mg/l, with values as low as 4200 mg/l and as high as 13,800 mg/l. Thus the total salinity of the extracts over-predicts the mean and maximum observed salinity by factors of 3.02 and 1.63 (saturated paste), 4.32 and 2.32 (first leach), and 6.0 and 3.23 (fourth leach). The most logical explanation for this is differences in the availability of salt to the water in the two systems. That is, in all the extraction techniques water is pervasively in contact with the solids and can reach all the available salt, whereas, in the field situation contact of water and sediment is limited.

CONCLUSIONS AND FUTURE DIRECTIONS

- (1) The ionic composition of groundwater in mine spoil is best approximated by the borehole composite of the first infinite dilution leach (about 10:1) although it is deficient in sulfate relative to the spoil water.
- (2) Water in glacial drift better approximates the composition of water in mine spoil than does water derived from bedrock. The water derived from bedrock has a composition very much enriched in sodium and bicarbonate relative to the spoil water.
- (3) The relatively high calcium and sulfate content of spoil water appears to reflect small amounts of highly saline drift or weathered bedrock mixed with larger amounts of less saline bedrock.
- (4) It is postulated that isolating the drift that contains high levels of secondary salt or oxidizable pyrite high in the overburden above the final post-mining water table will

result in spoil water composition that is lower in calcium, sulfate and total salt.

- (5) All three extract procedures over-estimate the total salinity of the groundwater. The first infinite dilution leach over-estimates the mean salinity by a factor of about 4 times. Presumably this reflects limited access of water to the salt within the spoil.
- (6) Further work is needed to assess the effects of saturation constraints and elevated levels of carbon dioxide, such as are found in spoil (Wallick, this volume) on the chemistry of the various extracts.
- (7) Exhaustive examination of existing shallow extract data is planned to further evaluate the conclusion that glacial drift and weathered bedrock are primarily responsible for the observed water chemistry in mine spoil.

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NUMERICAL MODELLING OF GROUNDWATER SYSTEMS
AND PREDICTION OF SALINIZATION POTENTIAL

by

Peter Fransham, Ph.D., P.Geol.¹

Craig Heath, M.Sc., P.Ag.²

¹Borealis Exploration Ltd., Calgary

²Hardy Associates (1978) Ltd., Calgary

ABSTRACT

There have been significant developments in the computer modelling field during the past decade. The net result of these developments is that numerical modelling of groundwater flow systems can be economically carried out for most reclamation projects.

A model capable of accurately predicting the position of the groundwater table and pore pressure distribution is presented. Two case histories are used to illustrate the potential application of the computer model. Since the cost of running the model is only a fraction of the total reclamation budget, then it should be possible to minimize the potential for salt by optimizing the regrading plan through computer modelling.

1.0

INTRODUCTION

There have been four major developments in the field of groundwater modelling. The first has been a dramatic decrease in the cost of computer systems, thereby making computer modelling economically viable for a wider variety of projects. The second is the increase in sophistication of the models, hence more realistic simulation of the natural environment. Thirdly, most students graduating with technical degrees have a basic understanding of computers and numerical models, and are able to provide required technical support. The fourth and by no means the least development has been the collection by government agencies of the parameters required to adequately calibrate the numerical model with good quality field data. With these developments, it is now possible to consider large scale numerical modelling of groundwater systems, and the build up of salts in agricultural lands.

Dry land salinity is a major problem in southern Alberta. Each year, considerable amounts of farm land are removed from production due to salinization. It is therefore important that reclaimed waste dumps and mines do not contribute to the salinity problems.

With the developments in groundwater modelling that are presented above, it is within the context of current technology and economy to model the groundwater systems that could lead to salinity problems. Once the system is understood, then various contour configurations can be tested numerically prior to costly implementation of the selected method.

This paper describes the results of modelling predicted the position of the water table during the growing season, as well as two dimensional modelling of flow in a clay slope. The model is a two dimensional finite element simulation which was based on a solution to Richard's equation of saturated-unsaturated flow. A computer program to solve the equations governing saturated-unsaturated flow was developed by Neuman et al. (1974). The program is capable of solving transient flow in saturated-unsaturated porous media. The program can handle non-uniform flow regions and can also simulate atmospheric boundaries and the uptake of water by plants.

The model has been successfully applied to a number of complex groundwater problems. Included in the list are: the prediction of flow into underground mine workings; seepage from impoundment structures (dams, sewage lagoons, tailings ponds); pore pressure distributions in unstable clay slopes and the position of the watertable during the growing season.

2.0 MODEL DESCRIPTION

2.1 INTRODUCTION

A detailed theoretical formulation of the model will not be presented here. Rather, an overview of the input parameters, a general description of the possible boundary conditions and the general capabilities of the model is discussed.

2.2 GENERAL INPUT DATA

Water is added to the ground surface by precipitation, overland flow, irrigation, or groundwater seepage, and is lost through discharge and evapotranspiration. The volume of water that is gained or lost is a function of: the existing soil moisture content; the relationship between soil moisture and suction; the hydraulic conductivity; and the elevation of the point in question with respect to the regional groundwater flow regime. Therefore, the model requires as input, the spatial distribution of the soils as well as their saturated-unsaturated hydraulic properties. In most areas of the province the geology is adequately known so that the distribution of surficial materials and their hydraulic properties can be estimated with sufficient accuracy for modelling.

Water is continuously gained or lost from the soil system. Therefore precipitation and evapotranspiration potential must be known within the area being modelled. These parameters can be obtained from climatic data and formulae respectively.

2.3 WATER UPTAKE BY PLANTS

The rate of water uptake by plant roots is in part governed by atmospheric conditions and in part by the soil parameters (i.e., soil type, moisture content, and position of the water table). For the model described here, it was necessary to restrict the root distribution to vertical rectangular zones. The size of the root zone can be specified for each plant type and by manipulation of a root effectiveness function, it is possible to follow changes in root development with time.

2.4 PRESCRIBED BOUNDARY CONDITIONS

A numerical model only simulates a portion of the total flow regime. In order that the model results bear some resemblance to the actual field situation, boundary conditions must be prescribed for the selected portion of the total flow regime.

In groundwater models there are essentially two types of boundary conditions - a prescribed flux boundary and a prescribed head boundary. Most models are assumed to extend down to an "impervious" base, where the prescribed flux is set equal to zero. The model sides are generally assigned head values, that are consistent with actual field values. It is important that the output be checked to ensure that the prescribed boundary conditions are not biasing the results. Should the results be affected by the boundary conditions, the size of the model must be increased or the boundary conditions must be changed with time to reflect the actual field values.

3.0 CASE HISTORIES

3.1 INTRODUCTION

To show the potential power of this particular numerical model, two case histories are presented. While the soil and climatic data are for the Ottawa Valley region, the methodology is directly applicable to Alberta. The first case history deals with one dimensional infiltration and evapotranspiration. The second case history is two dimensional flow through a clay slope.

3.2 ONE DIMENSION INFILTRATION

3.2.1 Introduction

A detailed study of one dimensional infiltration/evapotranspiration was carried out by Flores (1979). The site used for the study was located on level terrain. Land use was largely agricultural, with the principal crops being barley, oats and corn.

A typical soil profile is shown in Figure 1. The upper 0.5 m consists of an organic rich topsoil that developed on the underlying sand and sandy/silt layers. The silt and sand represent the final regression of the marine sea into which fine grained clay sediments were deposited. Saturated and unsaturated hydraulic conductivities as well as moisture characteristic curves for the soils have been determined by Topp et al. (1978). Water table elevations were recorded monthly by Agriculture Canada for a period of 5 years (1974-

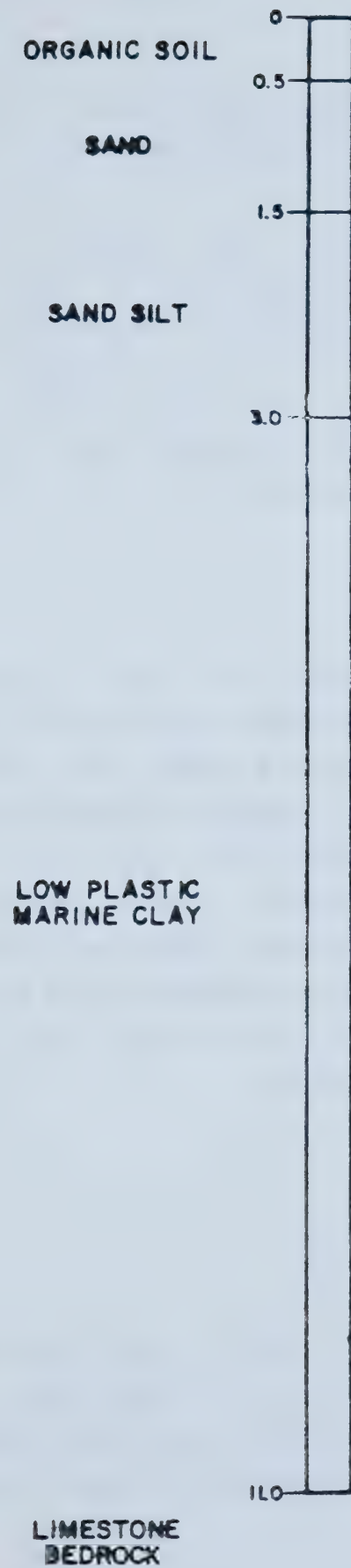


Figure 1 GENERALIZED SOIL COLUMN

1978). Open standpipes driven into the soil to depths of 1.0 m and 2.5 m, were used to monitor groundwater elevations.

Potential evapotranspiration was estimated (Baier and Robertson 1965). Rainfall records for the years in question were obtained from Environment Canada. To simplify the input data, the potential flux across the soil/atmospheric boundary was averaged over five days. The potential net flux and the cumulative flux for April to November 1975 are shown in Figure 2.

3.2.2 Results

The results of the simulation for 1975 are displayed in Figure 3. The measured groundwater elevations are shown as a solid line and the simulated as a dashed line. It is evident from Figure 3 that there is excellent agreement between the two curves. Since the measured data was taken on a monthly period, the measured curve does not show the fluctuations that are present in the simulated curve. While the simulated water table rises more slowly than was measured during the fall, the maximum drop of the water table during the summer was predicted with remarkable accuracy.

3.3 TWO DIMENSION FLOW

3.3.1 Introduction

Fransham (1980) completed a study of two dimensional flow through a layered slope. The site is located east of Ottawa. The slope is part of the proto-Ottawa River system. The channels have since been abandoned and no river or streams are

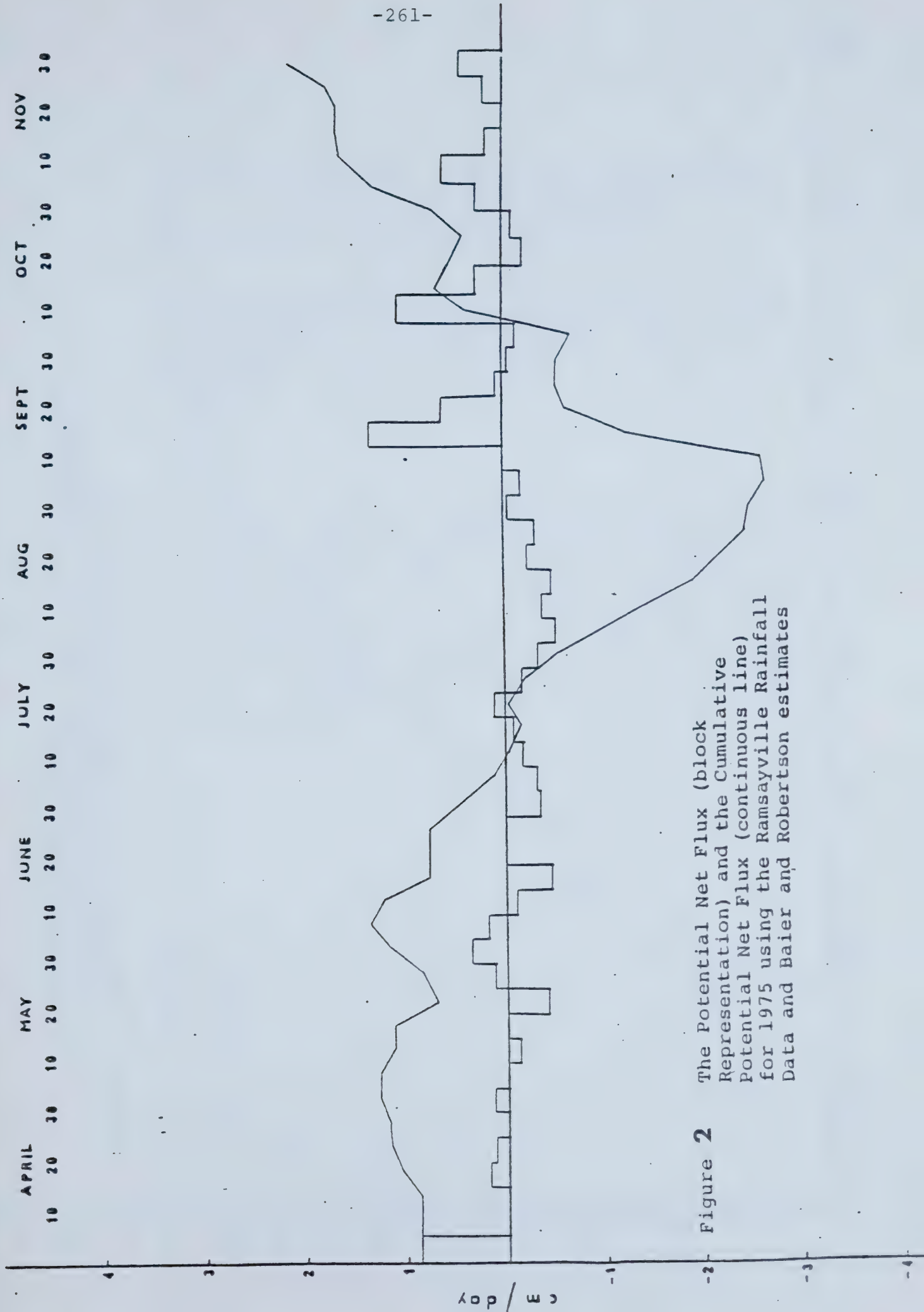


Figure 2 The Potential Net Flux (block representation) and the Cumulative Potential Net Flux (continuous line) for 1975 using the Ramsayville Rainfall Data and Baier and Robertson estimates

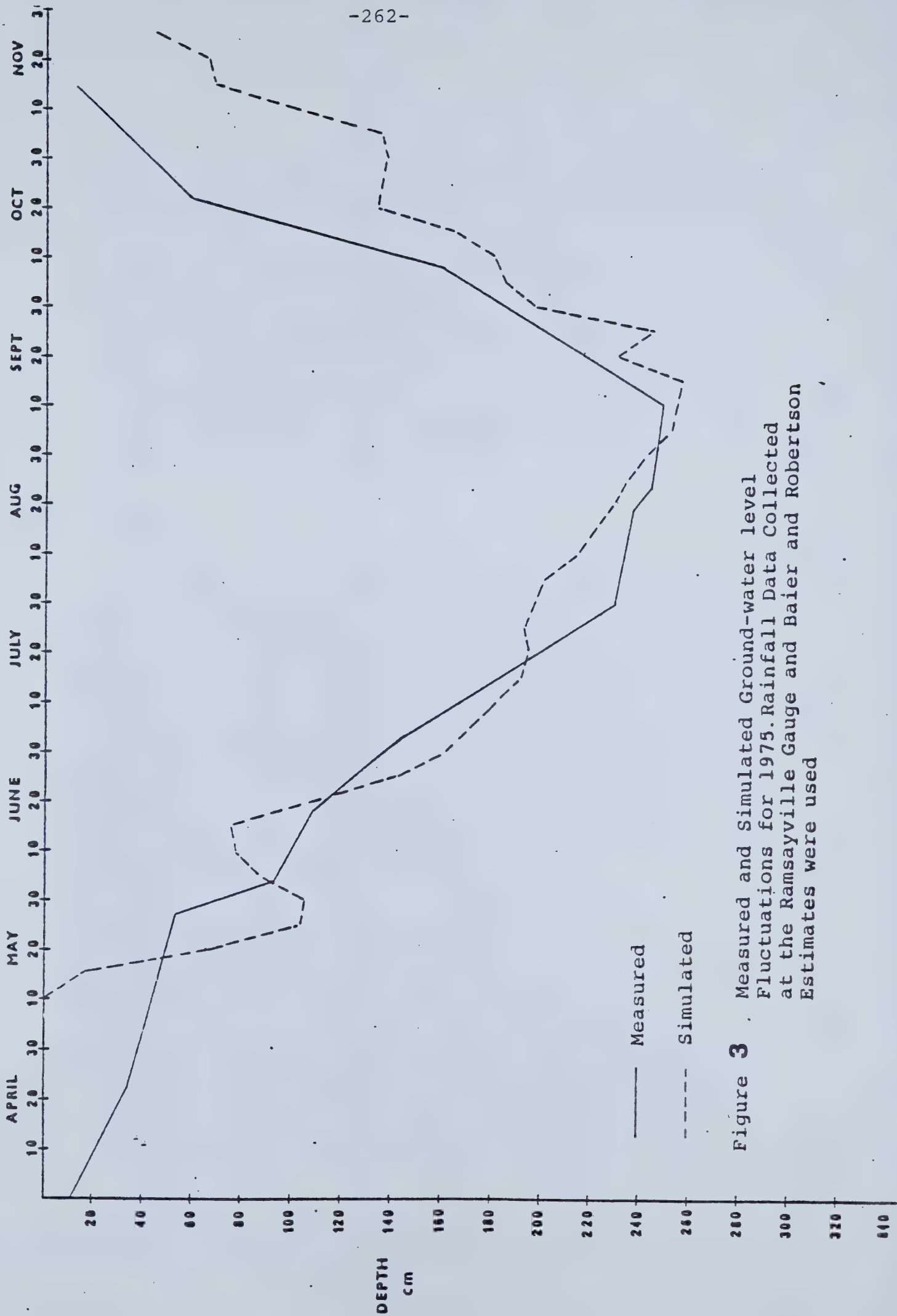


Figure 3 Measured and Simulated Ground-water level Fluctuations for 1975. Rainfall Data Collected at the Ramsayville Gauge and Baier and Robertson Estimates were used

close and the groundwater recharge is through precipitation only. The stratigraphy is shown in Figure 4 along with the mean piezometric heads as measured in piezometers.

Evapotranspiration was estimated using Thornthwaite's method, while precipitation records were obtained from the Ottawa Airport Weather Bureau. Climatic data and moisture balance are presented in Table 1.

3.3.2 Results

Hydraulic conductivities, and moisture characteristics were varied until a best fit was obtained between the measured and simulated piezometric heads. The hydraulic conductivities were then checked to verify that they fell within the normal range for the different soil layers. The results of the best fit analysis are shown in Figures 5, 6, and 7. Overall, there is good agreement between the measured and predicted piezometric heads.

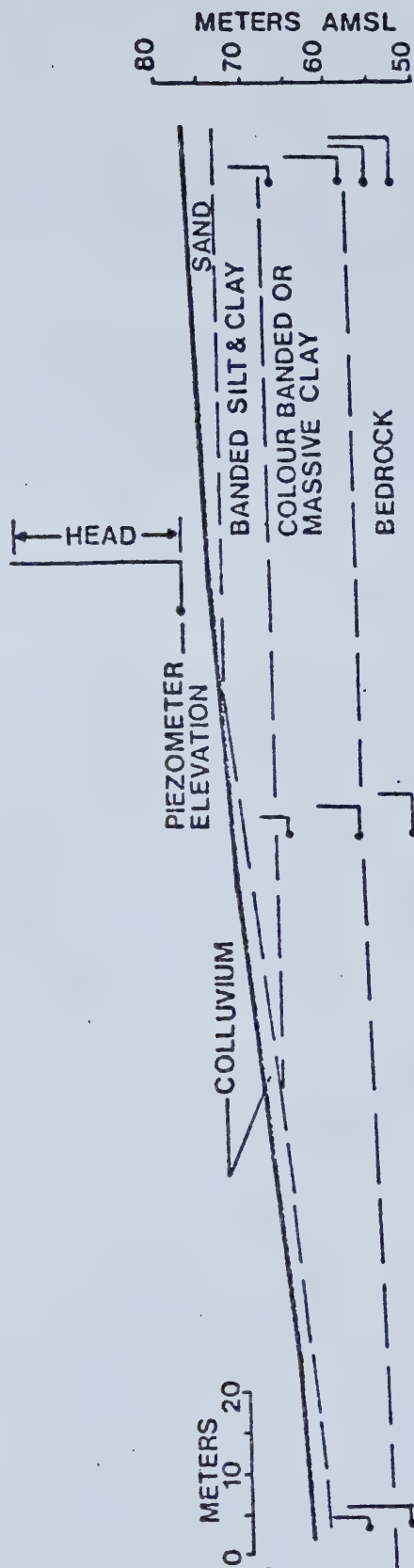


FIG 4
SITE P1 PROFILE & MEAN HEADS

MONTH	MEAN MONTHLY TEMP °C	MEAN MONTHLY PRECIP CM	POTENTIAL MONTHLY EVAPOTRANS CM	MOISTURE SURPLUS CM	MOISTURE DEFICIT CM
JAN.	-10.9	5.99	0.0	5.99	
FEB.	-9.5	5.69	0.0	5.69	
MAR.	-3.1	6.10	0.0	6.10	
APR.	5.6	6.76	2.90	3.86	
MAY	12.4	7.01	7.62		.61
JUNE	18.2	7.26	11.67		4.41
JULY	20.7	8.13	13.49		5.36
AUG.	19.3	8.15	11.56		3.41
SEPT.	14.6	7.87	7.43	.44	
OCT.	8.7	6.58	3.90	2.68	
NOV.	1.4	7.85	.47	7.38	
DEC.	-7.7	7.70	0.0	7.70	
TOTALS		85.09	59.04	39.84	13.79

Mean monthly temperatures and precipitation from Ottawa Airport Weather Bureau
Potential evapotranspiration calculated using Thornthwaite's method

TABLE 1 CLIMATIC DATA AND MOISTURE BALANCE FOR OTTAWA

FIG 5 COMPARISON OF MEASURED AND
CALCULATED PRESSURE HEADS
SITE P1 CREST

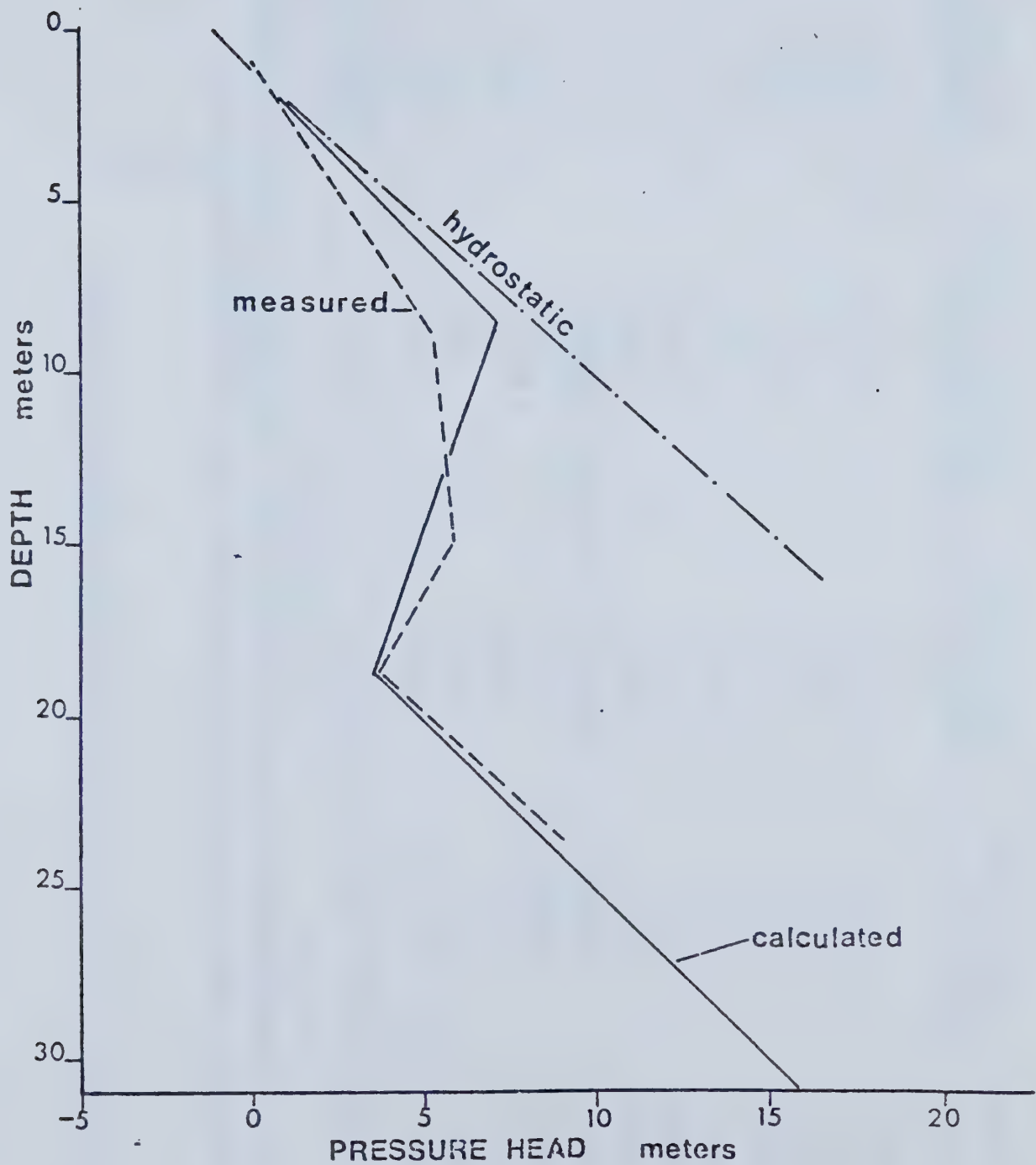


FIG 6 COMPARISON OF MEASURED AND
CALCULATED PRESSURE HEADS.
SITE P1 MID-SLOPE

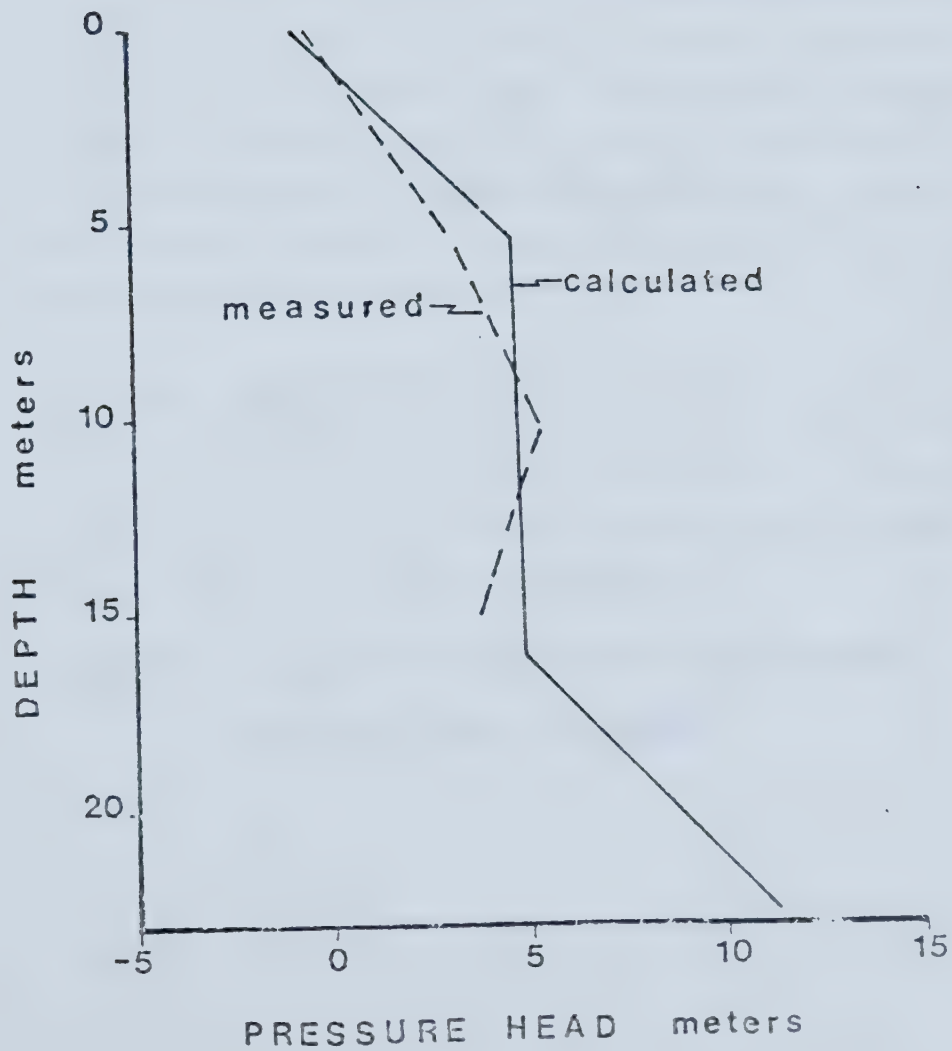
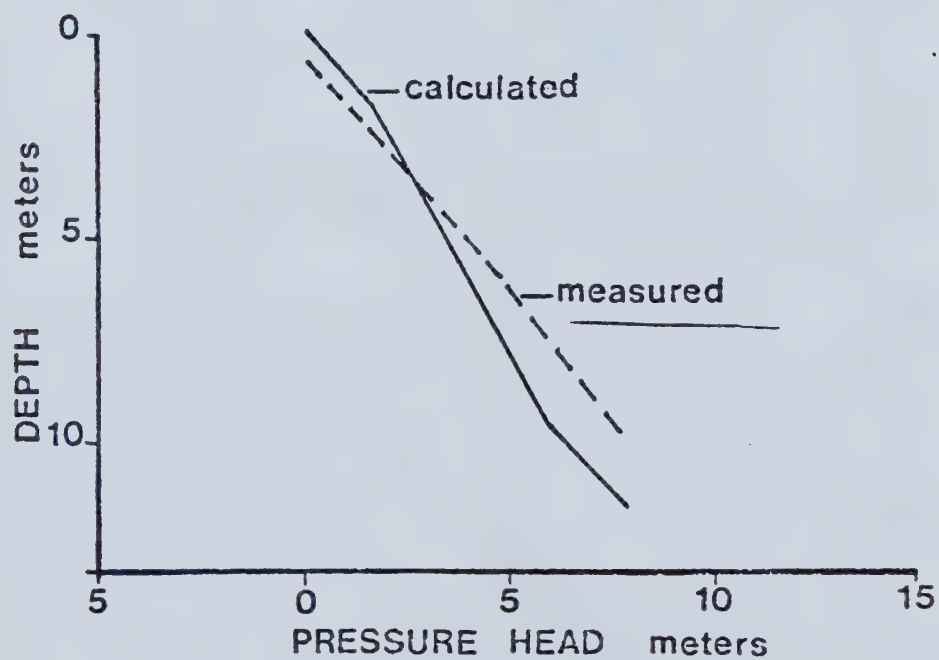


FIG 7 COMPARISON OF MEASURED AND
CALCULATED PRESSURE HEADS
SITE P1 TOE



4.0 MINIMIZATION OF SALINIZATION POTENTIAL

Pawluk (1973) has suggested that if the water table is within 1 m of the ground surface, there is a high potential for surface salinization. If the groundwater table is between 1 and 2 m deep, then there is a potential for salinization in the upper metre, and deeper than 2 m there is a sharp decrease in the extent of salinization in the top metre. The case histories presented in the previous section show that numerical modelling is capable of predicting the position of the groundwater table with sufficient accuracy that Pawluk's criteria for salinization potential could be applied to the results of the numerical model. Furthermore, the model is capable of calculating water losses to the atmosphere at discharge locations. If the initial groundwater chemistry is known, then it should be possible to estimate the volume of salts remaining in the soil with time.

A further benefit of numerical modelling is that various contouring scenarios can be evaluated prior to implementation. If the model shows that salt build up could be a problem, then contouring, plans can be made to optimize the control of salt buildup before costly field implementation.

5.0

COSTS

The program can be run on a microcomputer (e.g., IBM Personal Computer). The size of the computer required costs about \$10,000.00 (1983 dollars). Since all computer time is subsequently free, it is feasible that complex models could be run relatively inexpensively. The major cost in computer modelling is no longer for computer time, but in the systematic collection of input data and the translation of the data into a computer compatible form.

6.0

SUMMARY AND CONCLUSIONS

A numerical model has been described which is capable of accurately predicting: the position of the groundwater table; the pore pressure distribution within the flow region; and the water loss through discharge and evapotranspiration.

Numerical modelling has now developed to the point, and computer costs have been reduced to manageable levels, that it is possible to justify numerically modelling as part of most reclamation projects.

The potential fo eliminating additional costly unforeseen problems that may develop following reclamation more than offset the cost of the modelling.

7.0

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SOIL MOISTURE MOVEMENT STUDIES ON RECLAIMED
AND UNMINED LAND, BATTLE RIVER AREA,
EAST-CENTRAL ALBERTA
(Preliminary Results, 1981)

by

A.E. Howard and S.R. Moran

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ABSTRACT

This is a descriptive analysis, based on one year of data collection of unsaturated flow in various mined and unmined settings. Procedures involved study of both natural soil water movement from precipitation events, and forced water movement through flooding selected sites. Results show that moisture movement at three undisturbed sites is strongly affected by soil and subsoil layering. Moisture movement at the reclaimed sites is generally controlled by the presence of macropores within the subsoil spoil.

INTRODUCTION

PLAINS HYDROLOGY AND RECLAMATION PROJECT

This report presents a portion of the results of the Plains Hydrology and Reclamation Project (P.H.R.P.), the Alberta Research Council's long-term study of reclamation of surface coal mines in the plains of Alberta. The majority of the funding of this project has come from the Land Conservation and Reclamation Council of the Alberta Government through the Reclamation Research Technical Advisory Committee (R.R.T.A.C.) and has been administered through the Research Management Division of Alberta Environment. This study has been possible only because of the very high level of cooperation and support of the electrical utilities, (Alberta Power and TransAlta), mining Companies (Manalta Coal and Luscar Ltd.), and numerous private citizens on whose property and with whose data we have worked.

Project Overview

The objective of this project is to develop a predictive framework that will permit projection of success for reclamation and impact of mining on water resources on a long-term basis. Differences in physical and chemical properties of the premining soils, overburden, and subsurface water will be used as keys to project postmining conditions. The predictive framework is to be based on an understanding of processes acting within the landscape so that in the future, mine sites that are not totally analogous to those that have been studied can be evaluated as well.

The project involves a holistic approach to reclamation by integration of studies of geology, hydrogeology, and soils, not only in a proposed mining area, but also in the adjoining unmined areas. This approach will permit the assessment of impacts and long-term performance, not only in the mined areas, but also in the surrounding area.

Project Rationale

As Alberta confronts the need for expanded development of coal resources in the coming decade, major concerns about the environmental impacts of

mining and reclamation of mined areas remain unanswered. Most of the land that is underlain by minable coal in the plains area of the province is in agricultural production. Groundwater, which is commonly derived from coal beds, supplies nearly all the water needs of the region.

To the degree that surface mining of coal threatens to disrupt the long-term agricultural productivity or the availability of a potable water supply, it threatens the very economic life of the plains region. Government regulations are promulgated to direct mining activities in such a way that these perceived environmental threats are minimized. However, because these regulations must be conservative, they often are required to react to the risk of problems in the absence of supporting scientific evidence. Research into the potential problem then provides the scientific basis by which the initially arbitrary regulations can be rationalized, i.e., strengthened or rolled back depending on the scientific findings.

Reclamation research in Alberta and other parts of North America has concentrated largely on establishing soils and vegetation on graded overburden materials. Little work has focused on the long-term productivity of these reclaimed landscapes or on the long-term impacts of mining on water resources. Existing research and field experience in working mines suggest that in most places revegetation of graded, topsoil covered mined spoil is feasible. It is not clear whether salts liberated within the mine spoil will migrate into the replaced soil and degrade it or whether these salts will produce seriously degraded water quality in groundwater.

Project Objectives

The objective of this project is to develop a predictive framework that will permit projection of success for reclamation and impact of mining on water resources on a long-term basis. Differences in physical and chemical properties of the premining soils, overburden, and subsurface water will be used as keys to project postmining conditions. The predictive framework is to be based on an understanding of processes acting within the landscape so that in the future, mine sites that are not totally

analogous to those that have been studied can be evaluated as well.

Objective A

To evaluate potential for reclamation of lands to be surface mined. The focus here is on features of landscape that make it productive in a broad sense not restricted to revegetation.

Sub-Objectives

- (A) (1) To assess and evaluate the potential for long-term degradation of reclaimed "soils" through salt build-up (including heavy metals).
- (A) (2) To assess and evaluate the effectiveness of topographic modification and selective placement of materials to mitigate deleterious impacts on chemical quality of groundwater.
- (A) (3) To assess the availability of water supply in or beneath cast overburden to support post-mining land use. Includes both quantity and quality considerations.
- (A) (4) To evaluate productivity potential of post-mining landscapes and the significance of changes in productivity as a result of mining.
- (A) (5) To assess and evaluate limitations to post-mining land use posed by physical instability of cast overburden.

Objective B

To evaluate the long-term impact of mining and reclamation on water quantity and quality.

- (B) (1) To assess and evaluate the long-term deterioration of quality of groundwater in cast overburden and surface water fed from mine spoil as a result of the generation

- of weathering products.
- (B) (2) To assess and evaluate infiltration, groundwater recharge, and groundwater-surface water interactions within cast overburden.
- (B) (3) To characterize the groundwater chemistry generated within cast overburden.

INFILTRATION AND GROUNDWATER RECHARGE

This report deals with studies directed at sub-objective B-2; To assess and evaluate infiltration, groundwater recharge, and groundwater-surface water interactions within cast overburden. It presents data and conclusions obtained from studies of water movement in the unsaturated zone and infiltration studies that were conducted during the first three years of the project, from 1979 through 1981.

Numerous studies in Alberta, Saskatchewan, Montana, and North Dakota have demonstrated that changes in agricultural land management practices, such as introduction of summer following, can significantly alter infiltration and groundwater recharge characteristics of landscapes (Black et al, 1981). Clearly, the total disruption of physical structure of soil and rock overburden in the mining process should produce a new material, mine spoil, with at least initially profoundly different infiltration characteristics than in the unmined case. As the mine spoil stabilizes and settles the infiltration characteristics of the landscape are expected to alter, very likely decreasing the rate at which water can enter the ground.

If infiltration and groundwater recharge rates are increased over those of the unmined landscape then the groundwater flow system will adjust by producing elevated water levels and increased areas of groundwater discharge. Just as is the case with saline seeps related to summer following in dry land agriculture, increased soil salinity would result. Because of the already elevated levels of salinity of groundwater in mine spoil large amounts of salt could potentially be transmitted to the land surface in this case.

If the final stable condition of reclaimed mine spoil results in lower infiltration and recharge rates than in the pre-mining landscapes, then the groundwater-flow systems will adjust by producing lower water levels and decreased groundwater discharge. In areas of extensive surface mining, such a condition could result in reduction of water supply available in shallow aquifers and reduction of base flow in some streams.

The present study was designed to assess infiltration rates in both unmined and reclaimed settings at the Battle River site. Continued work is underway to evaluate how infiltration characteristics change with time.

DESIGN OF
SOIL INFILTRATION AND REDISTRIBUTION STUDIES

Recharge through the unsaturated zone is being evaluated by studying natural soil moisture flow as well as through a more controlled moisture regime, and infiltration and moisture redistribution study that was expanded during the 1981 field season.

SITE SELECTION

In late 1980, three infiltration plots were constructed on undisturbed land on soil associations that were representative of those originally in the study area, Red Willow - Foreman (BR 50), Elnora-Killam-Foreman (BR 62), and Sullivan Lake-Torlea (BR 48) (see Figure 1). Infiltration plots at two of these sites were constructed on the soils of potential recharge areas, the soils of the Red Willow and Elnora Series, as well as one plot on a soil of the Torlea Series.

During May and June of 1981, five more plots were constructed, all on reclaimed land. Three of these were selected in the Diplomat Mine (see Figure 1) to be representative of different materials-handling methods. Site BR 59 is located in an area where mine spoil had been ripped prior to topsoil placement. This area was seeded for the first time since reclamation, the crop being wheat. The second site (BR 58) is located on land where spoil was not ripped prior to topsoiling. This field had been previously cropped but was fallow during the 1981 crop year. The third site, BR 60, had been reclaimed for a longer period of time and is growing a deep rooted crop, alfalfa. At this location, topsoil was not segregated from spoil during the mining and reclamation process.

Two plots were selected at Vesta Mine, where alfalfa has established on land where the topsoil, till and bedrock spoil had been segregated. Both sites, BR 52 and BR 56, occupy upslope positions in relation to a central pond (Figure 1).

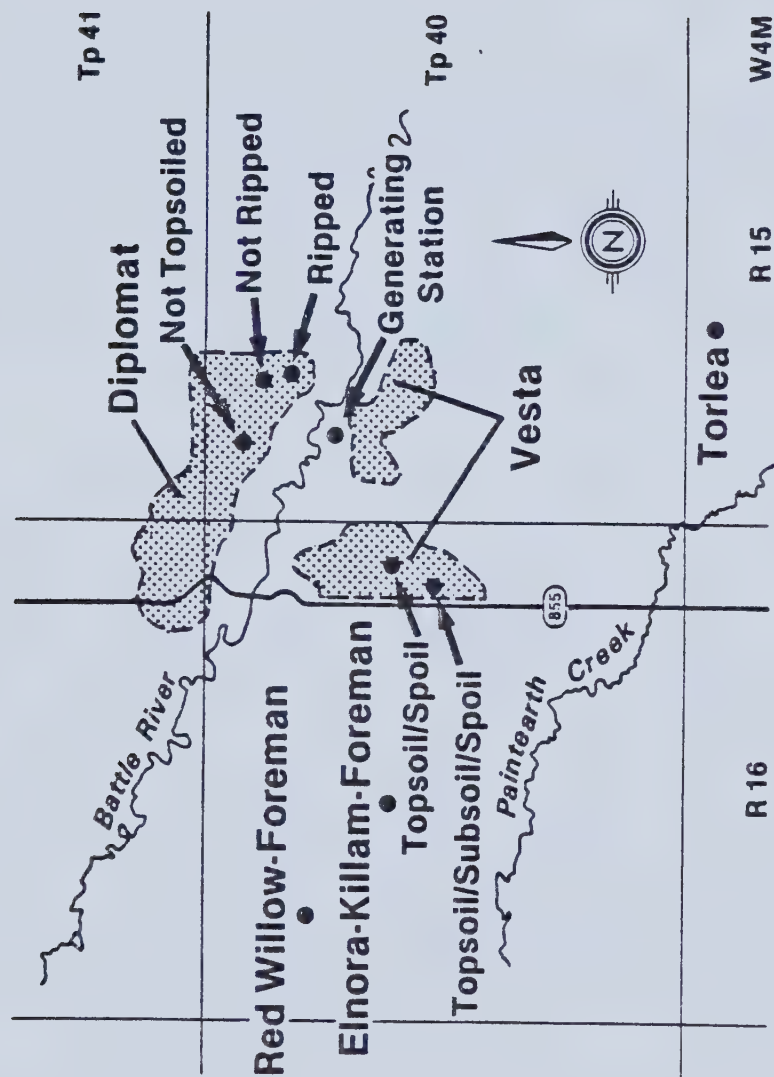


FIGURE 1. Flood test sites at the Battle River study area.

METHODS

Plots were constructed to provide a physical barrier against lateral soil moisture movement by bordering all four sides of each plot with sheets of plywood that were joined to form a square enclosure. The sides of the plot were excavated by trenching, and the plywood enclosure was then pre-assembled and lowered to a depth of 1 m into the trenches. The enclosure was lined with plastic to prevent leakage before the trenches were backfilled. This method provided means by which water could be ponded upon the plot to a maximum depth of 25 cm. Plot instrumentation consisted of a neutron probe access tube to allow measurements to a depth of 4 m, 4 tensiometers, and 4 porous cup samplers, one each at depths of 50 cm, 1 m, 2 m, and 3 m.

All plots were flooded during the months of July and August 1981. Depth of flooding was 20 cm of water, where possible, and measurements were made by noting the time required for the water level to drop in 2.5 cm increments. All 5 plots installed on reclaimed lands developed leaks between the soil and the plywood border. Infiltration data is not available for four of these plots as a result of the leakage, but BR 60 was successfully repaired after an initial flooding, and reflooded two weeks later. The average infiltration rates are presented in Table 1.

Post-flooding soil moisture redistribution data was collected for all sites, and soil moisture profile curves have been included in this report. It should be noted that additional measurements were taken for each flooding event, but the figures presented show only those that display the most relevant information.

Table 1. Infiltration rates for flood test sites.

Site	Average Infiltration Rate (cm/min)	Depth of Water Applied (cm)
BR 48	0.007	20
BR 50	0.171*	37*
BR 60	0.050	20
BR 62	0.083	25

* Two successive floodings were performed at this site. Average Rate for first flooding (20 cm) is 0.601 cm/min, average rate for second flooding (17 cm) is 0.091 cm/min.

RESULTS AND DISCUSSION

UNMINED LAND

BR 48

This site consists of instrumentation upon soils representative of two associated series. One location is on the Torlea Dark Brown Solodized Solonetz derived from shale bedrock, the other is on a Sullivan Lake Dark Brown Solodized Solonetz developed in a coarse-textured veneer overlying the bedrock.

Moisture redistribution following the flooding event also shows that water movement was slow, however there was a definite positive change in water content at the 1 m depth, indicating that a net downward flow was occurring. The lack of change in percent moisture content at 50 cm in the neutron probe data, coupled with the very vague relationship between the tensiometer data (not shown) and the neutron probe data (% H₂O) in Figure 2 suggest that the majority of downward flow is through macropores such as cracks and structural joints. Water movement in this form could "bypass" the instruments at some depths and be detected at others.

BR 50

This site consists of instrumentation at two locations, the upper slope one on a soil of the Red Willow Series, a moderately well drained Orthic Black Chernozem derived from sandy alluvial materials overlying glacial till. The other location is a lowerslope position on a soil of the Foreman Series, a poorly drained Thin Black Solonetz that has developed directly upon the glacial till. The glacial till has several layers of coarse-textured material incorporated within it.

The lowerslope position has been an area of frequent ponding from spring runoff and, as a result, it had been used as a pasture until 1981, when it was seeded to a small grain crop midway through the growing season. The farmer has recently learned that surface drainage had initially been to the north but the route had been blocked by a dike about 30 years ago in order to allow a slower, more easterly flow to act as flood

Soil Infiltration Data: Torlea

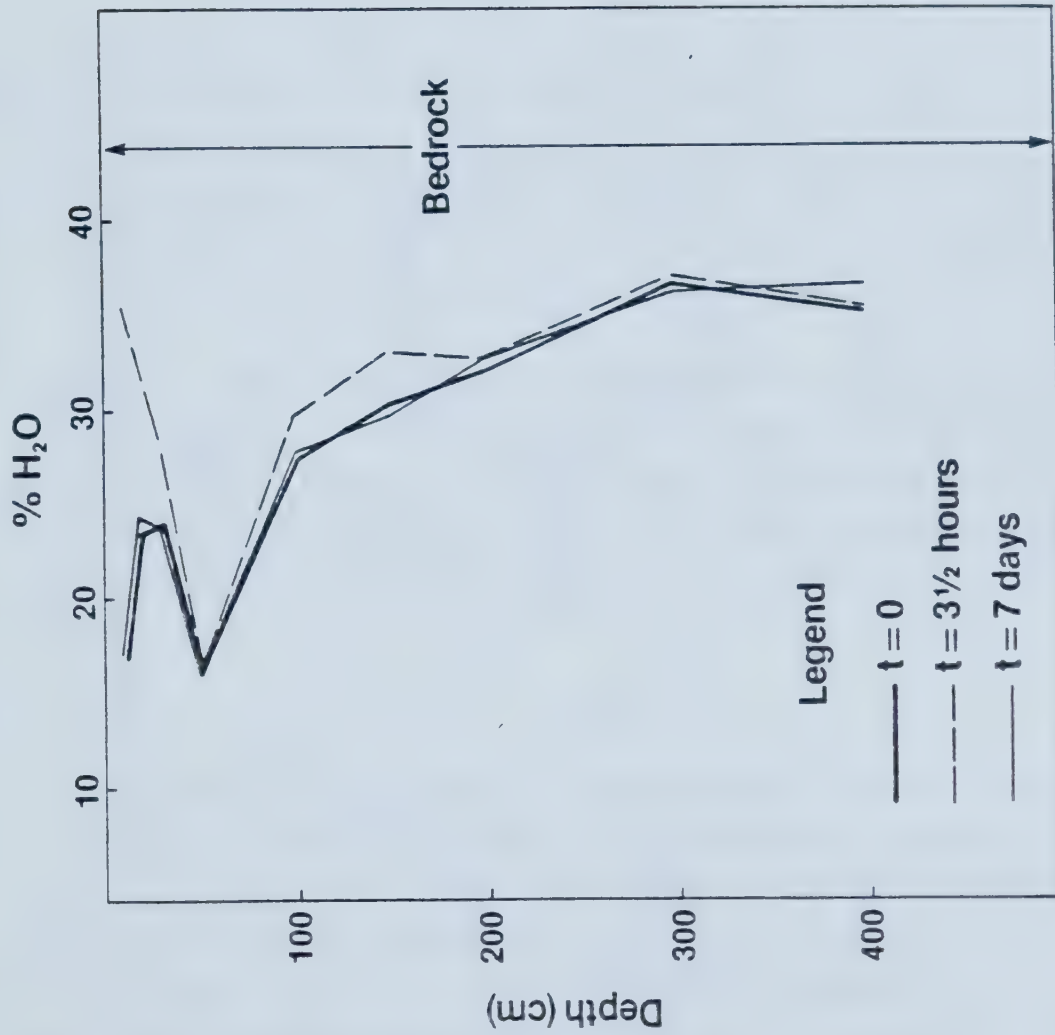


FIGURE 2. Flood test results from 1981.

irrigation on a nearby field. This is believed to have caused the ponding at the lowerslope site, and recent removal of the dike is expected to minimize the problem and allow earlier access to that area.

The infiltration tests were conducted on the upper slope site, which is located on a partially cleared portion of the pasture where native grasses and shrubs dominate. Depth of the alluvial material is 110 cm. The depth to the water table is approximately 3 m at the upper location and 2 m at the lower location.

Results of the infiltration tests showed that the Red Willow soil site had the fastest infiltration rate of all the sites that were tested. Since only 15 cm of water could be applied at one time, two successive floodings were performed to ensure there was sufficient moisture available to effectively interpret the moisture redistribution characteristics.

Monitoring the post-flood water movement showed that no water movement is detected at the 2 m depth or lower (Figure 3). It appears that the moisture is moving laterally along a gravel layer at the sand-till interface or else along the numerous gravel layers present within the till, or both. This is consistent with the data presented in the 1981 Annual Report.

BR 62

Site BR 62 consists of instrumentation in an upslope, midslope, and a lowerslope position, representing an association of three Series of till-derived soils commonly found in the area. The upslope position of the site is located on a soil of the Elnora Series, a well-drained Eluviated Black Chernozem. The midslope portion of the site is on a moderately well-drained Killam Thin Black Solodized Solonetz while the lowerslope position is located on an imperfectly to poorly-drained Foreman Black Solonetz. The tills of the area have scattered inclusions of coarse-textured material occurring in lenses and layers at varying depths. The thickness of till at this site is about 6 m with a sand and gravel layer found at the depth 2 m in the upslope position and a

Soil Infiltration Data: Red Willow

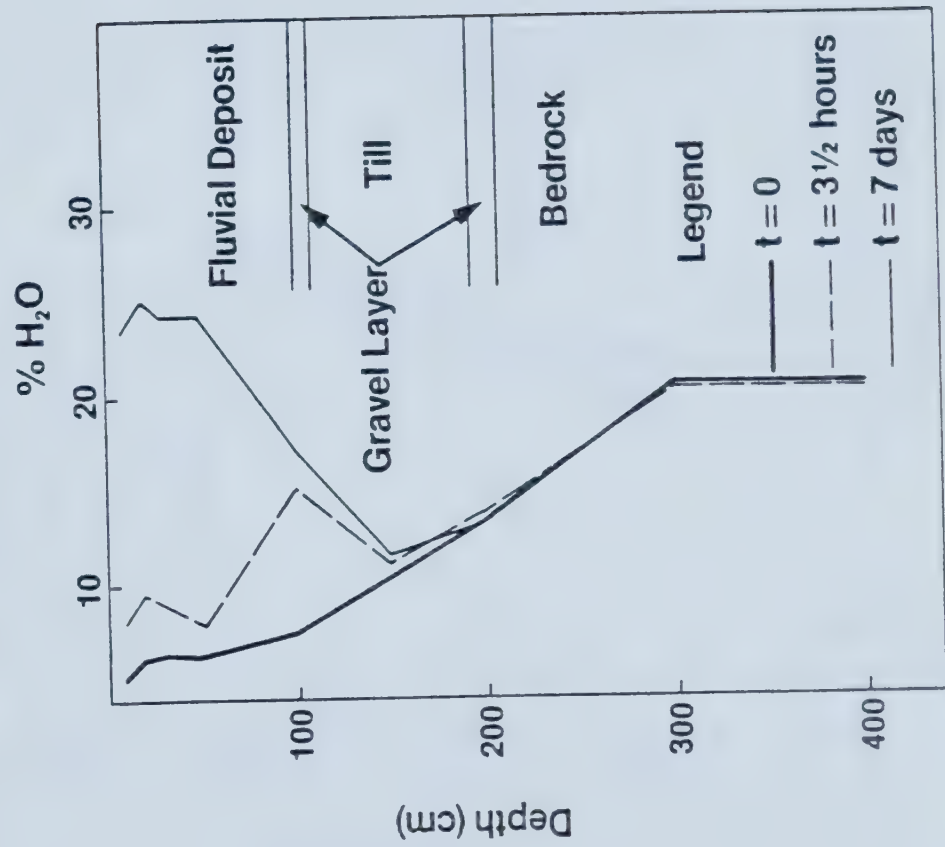


FIGURE 3. Flood test results from 1981.

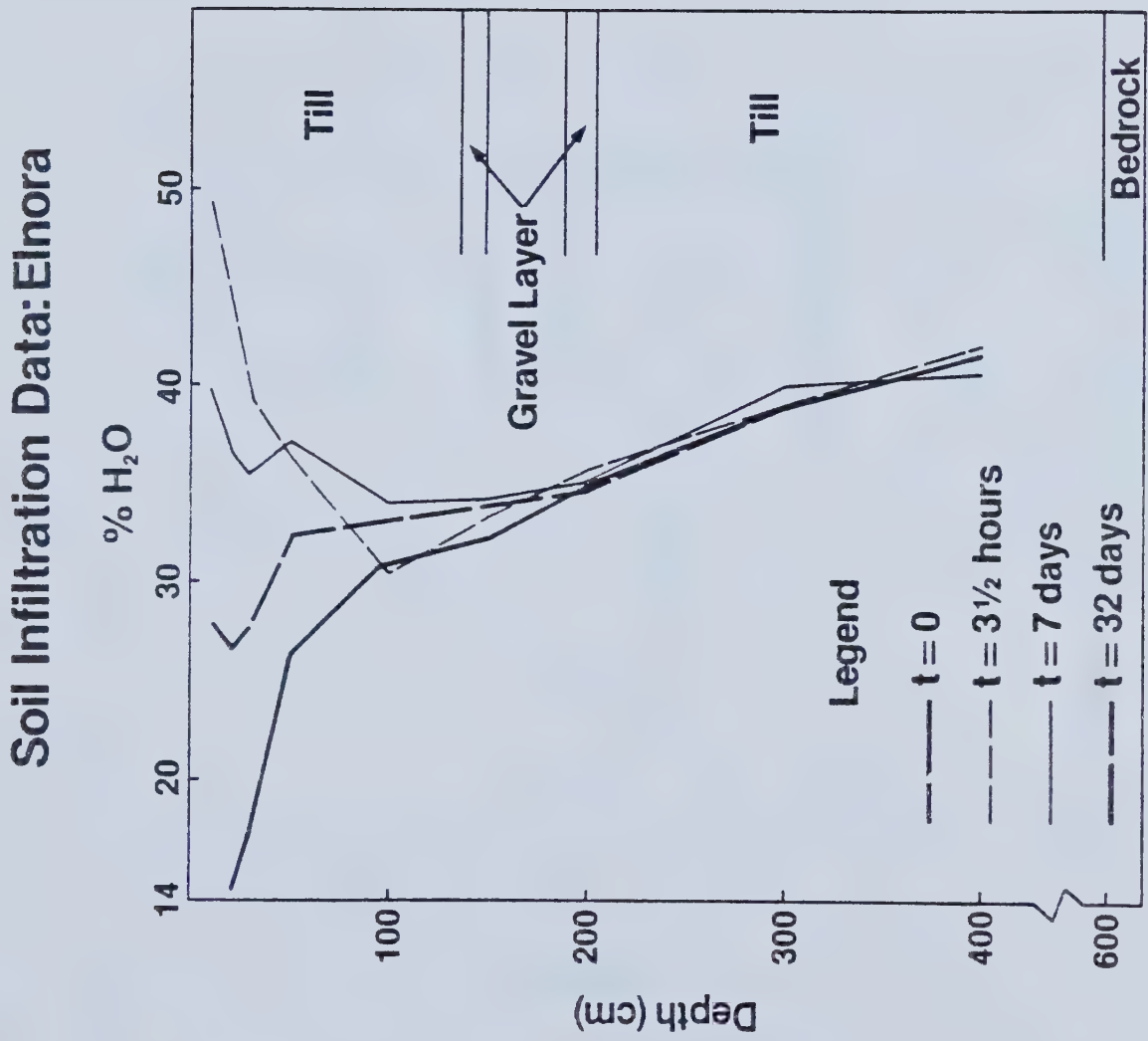


FIGURE 4. Flood test results from 1981.

sandy layer at the 4 m depth in the lowerslope position. The water table fluctuates about a depth of approximately 4 m at the upper location, 3 m at the midslope, and 2.7 m at the lower slope location.

The infiltration study occurred at the upslope nest of instruments and moisture redistribution data from Figure 4 show that a small amount of moisture was detected at 3 m by the neutron probe, 5 days after flooding. The 3 m tensiometer does substantiate this, despite the leakage problems that developed with this tensiometer during the initial stages of the flooding. Pre-flood tensiometer data (not shown) shows a zone of near-saturation at the 2 m depth, where the layer of sand and gravel is located. The lack of moisture-response by the instruments below the 2m depth indicate that the majority of downward flow is halted or becomes lateral flow when it contacts this layer.

RECLAIMED LAND

Only one of five sites on reclaimed land did not leak when flooded. However, data on moisture redistribution from the other four sites provide useful input to assessing how infiltration at reclaimed sites differ from unmined sites.

BR 52 (Vest Mine Spoil)

The 60-minute moisture content curve in Figure 5 shows a "bypassing" of the 20 cm and 30 cm depths, which indicates that there is some water movement through macropores within the top 1 m of the plot. Subsequent movement is low and may have stagnated near the 2 m depth since the tensiometer curve for the 20th day after flooding is the same as that for the 42nd day. Neutron probe data for day 42 is not available to confirm this, however. It does appear that the majority of the applied water was lost to evapotranspiration while still within the upper 1.5 m; that moisture which was detected below 1.5 m was small in volume and was not detected below 2 m. Further study will be needed before it can be determined whether the subsoil-spoil interface at 210 cm is actually interfering with downward moisture flow.

Soil Infiltration Data: Vesta Topsoil/Subsoil/Spoil

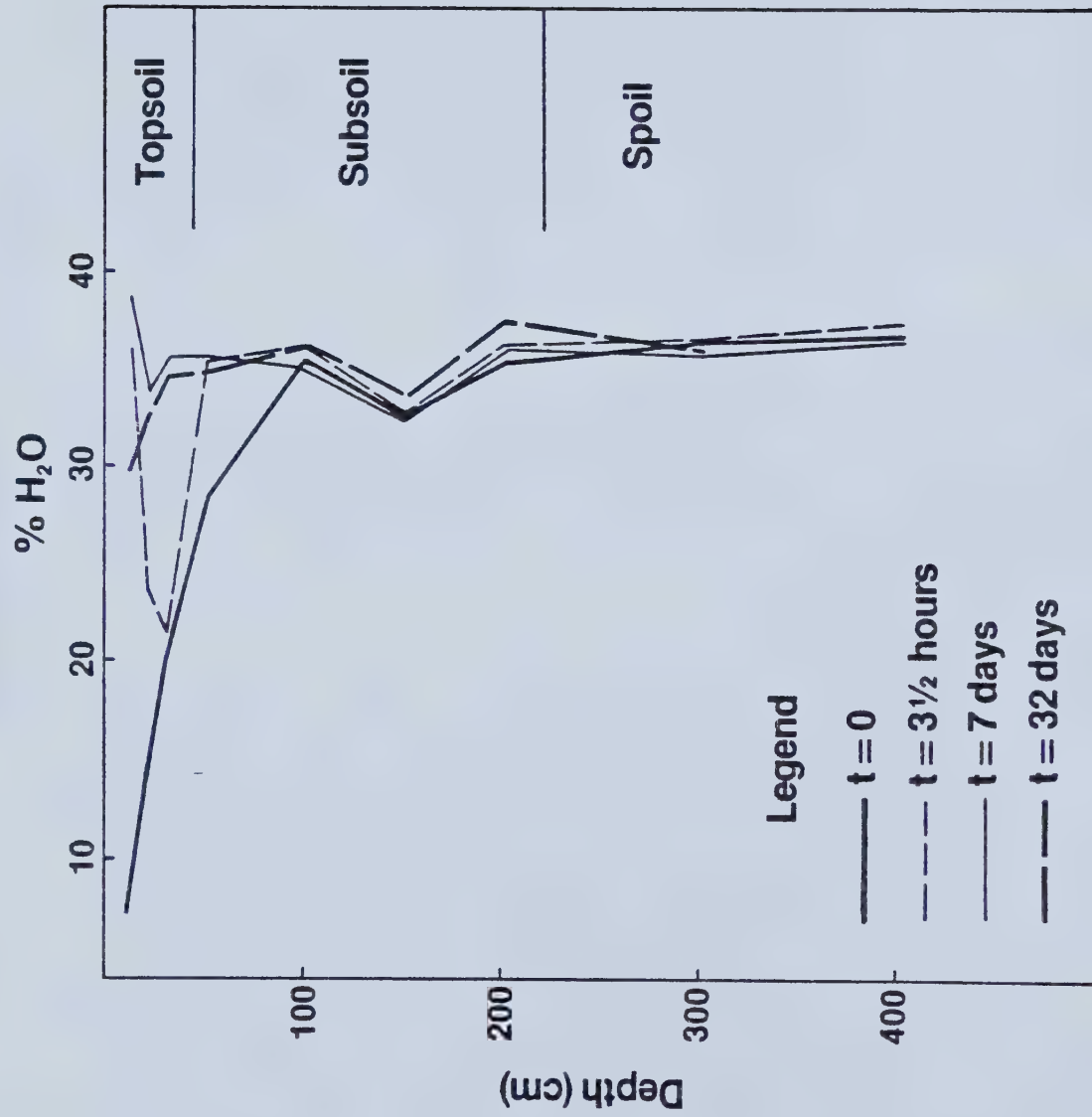


FIGURE 5. Flood test results from 1981.

BR 56 (Vest Mine Spoil)

Water movement data in Figure 6 shows that there were two rates of flow. On the 15-day curve there is a response at 3 m in the neutron probe data which is supported by a corresponding decrease at 2 m in the tensiometer data (not shown). The wetting front described by this data is rapid and very uneven, typical of movement through interconnected macropores and fissures. Studies of reclaimed land in Montana have shown that similar patterns of rapid initial wetting have been observed, and persist all the way to the base of the spoil (Dollhopf, personal communication). A second wetting front is shown near the 2 m depth by the 32 day water content. This front appears to be an indication of a more uniform wetting. The topsoil-spoil interface, located at 20 cm, does not appear to be inhibiting moisture movement at this site. It is concluded that recharge of this site will occur more frequently from the initial, rapid flow through large openings, than from the slower, more even wetting front.

BR 58 (Diplomat Mine Spoil)

After flooding, this site displayed the most prominent leakage of all sites and upon completion of the infiltration event, a large crack opened up across the plot. During this time the plot surface settled 10 cm from its original elevation. The field that was chosen for this site was not ripped prior to topsoil placement, and field staff had observed the development of some small depressions caused by differential settlement. The redistribution data has identified two means by which downward flow is occurring, initially through macropores and fissures, and secondarily as a slower, more uniform wetting front. Neutron probe measurements show a response at the 1.5 m depth 30 minutes after flooding and at the 3 m depth after only 72 hours (Figure 7). This is strongly suggestive of the initial, rapid wetting through macropores and fractures. The secondary flow has been steady and progressive such that after 64 days moisture increases were being detected at 3 m by the tensiometers, and 4 m by the neutron probe. Both methods of flow are moving out of the range of measurement and toward the water table, and should be considered potential recharge although the initial, rapid flow will be more frequent recharge.

Soil Infiltration Data: Vesta Topsoil/Spoil

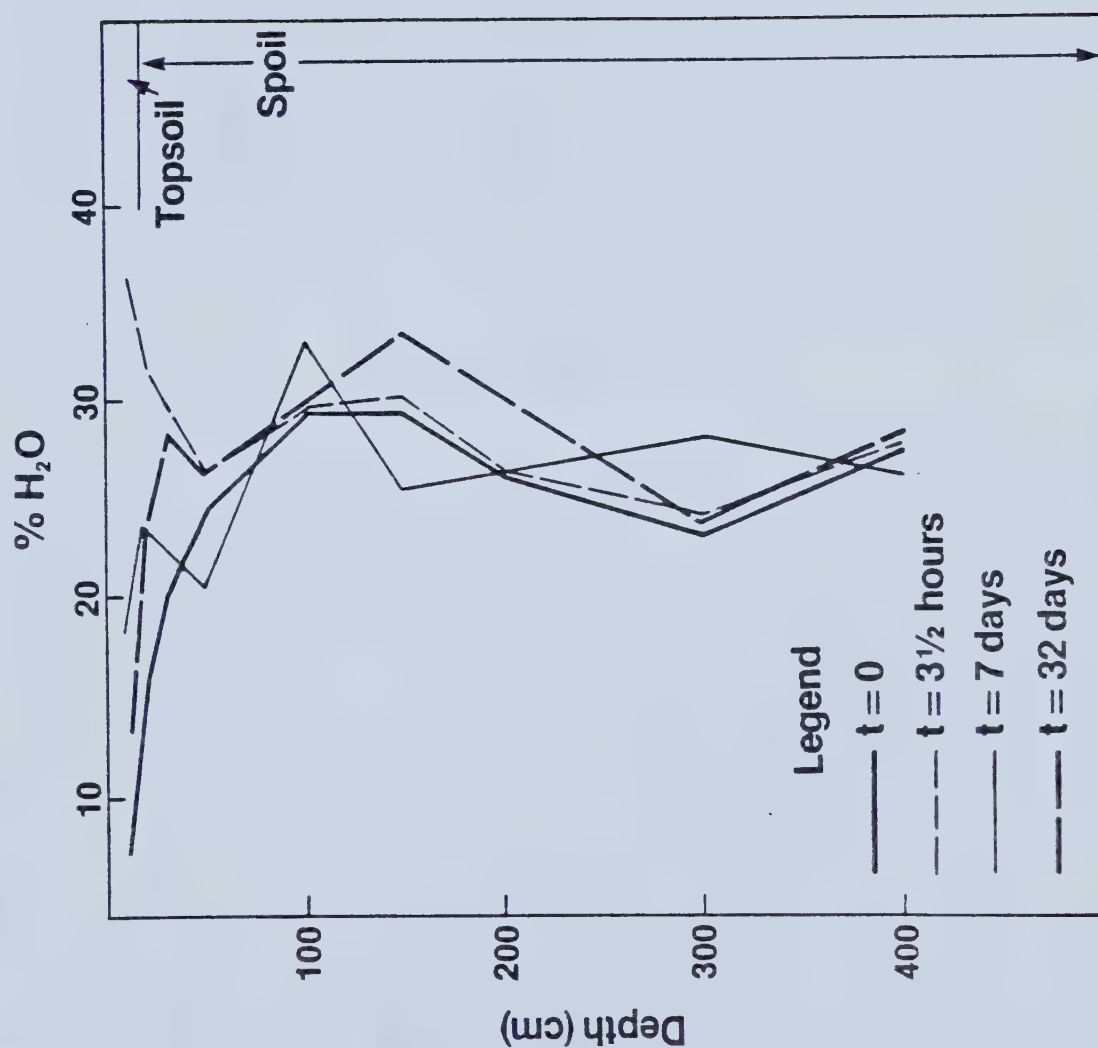


FIGURE 6. Flood test results from 1981.

Soil Infiltration Data: Diplomat Not Ripped Prior to Topsoiling

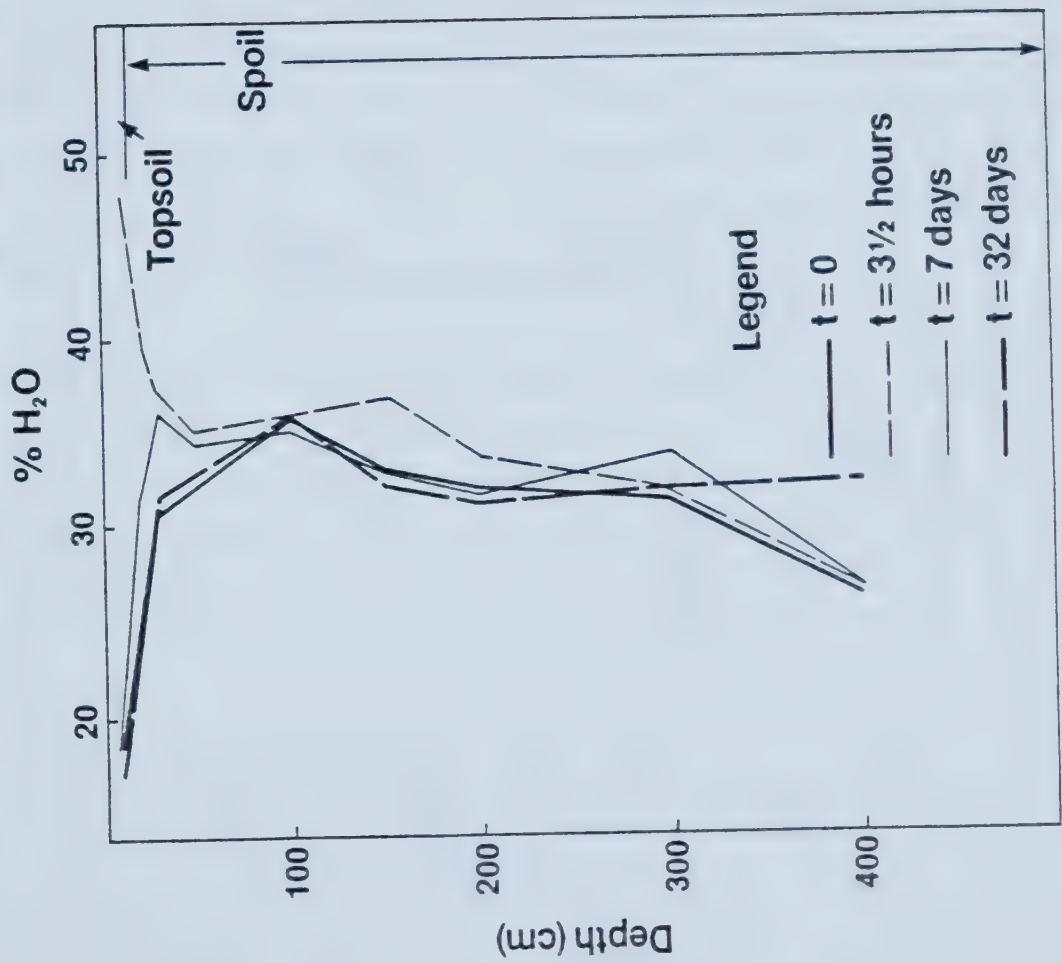


FIGURE 7. Flood test results from 1981.

BR 59 (Diplomat Mine Spoil)

Although this plot developed leaks immediately after flooding, no cracks across the plot face or settlement were observed. There is also no evidence in the moisture redistribution data to indicate that the rapid, macropore movement that was evident in BR 58 is a significant component of low here (Figure 8). All tensiometers recorded an initial decrease in suction that has been attributed to leakage of water down along the sides of each tensiometer. After 13 days, they had all recovered from this effect. The steady progressive type of flow that was observed in BR 58 appears to be occurring at this site, however, problems with the neutron probe prevented us from tracking it beyond 50 days. Because of the lack of observed water movement through macropores, it is unlikely that recharge is as common an occurrence at this site as it is at site BR 58.

BR 60 (Diplomat Mine Spoil)

Water redistribution curves in Figure 9 show that no response to the flooding was detected below the 2 m depth by the neutron probe. Leakage problems developed with the tensiometers and the rapid response of these to the water application is probably due to some water movement down the holes in which the tensiometers were placed. No such problems were noted with the neutron probe access tube.

Two flood tests were performed here, the first one produced minor plot leakage and the test was halted. Once the plot was repaired, a second flooding was performed, two weeks after the initial one. Since infiltration data is being used at this time for comparison of reclaimed vs. undisturbed land, the most suitable site on undisturbed land that can be compared with BR 60 is BR 62 Upper. The average bulk density for the top 40 cm at BR 62 Upper is slightly less than that for site BR 60, also the surface texture is more coarse at BR 62 Upper (a loam vs. a clay-loam). These factors, plus the presence of a developed Ah horizon in the Elnora-Killam soil led to an assumption that the infiltration rates at BR 60 would be less than those at BR 62 Upper. Data from Table 1

Soil Infiltration Data: Diplomat Ripped Prior to Topsoiling

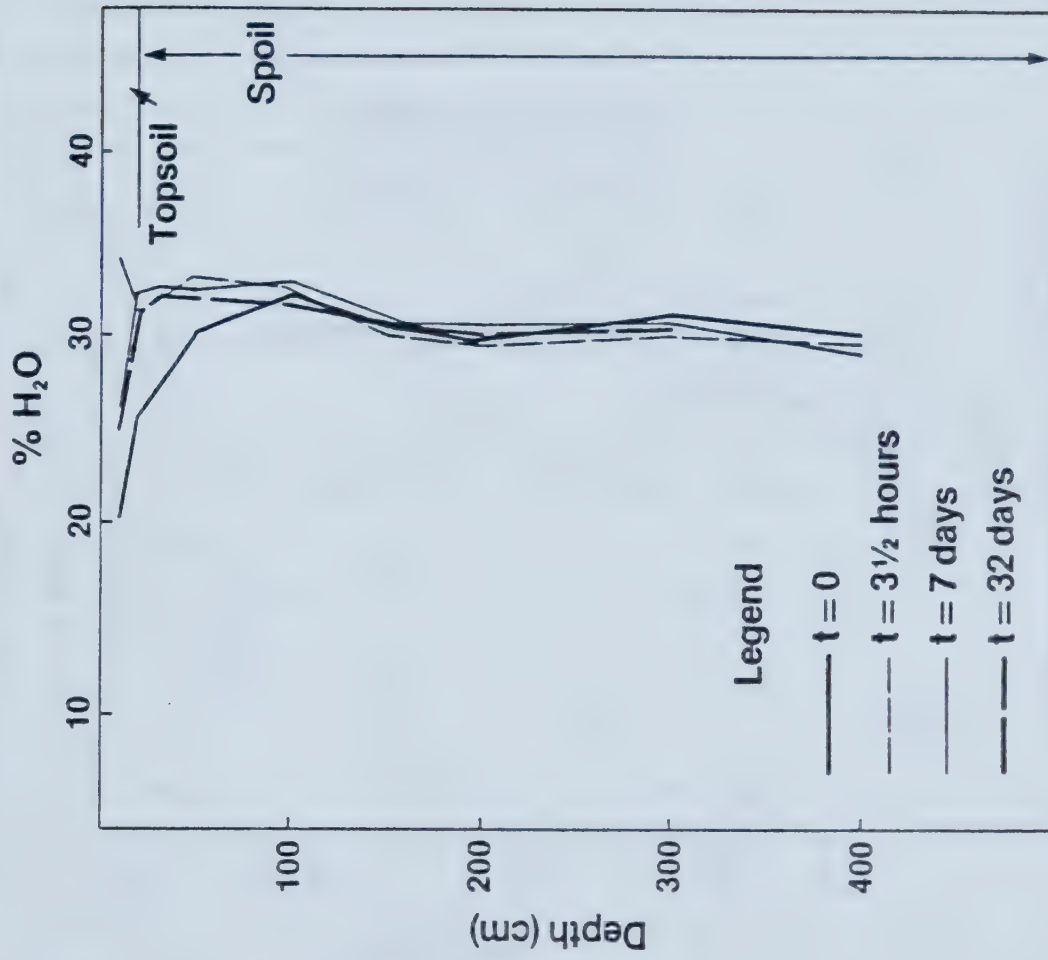


FIGURE 8. Flood test results from 1981.

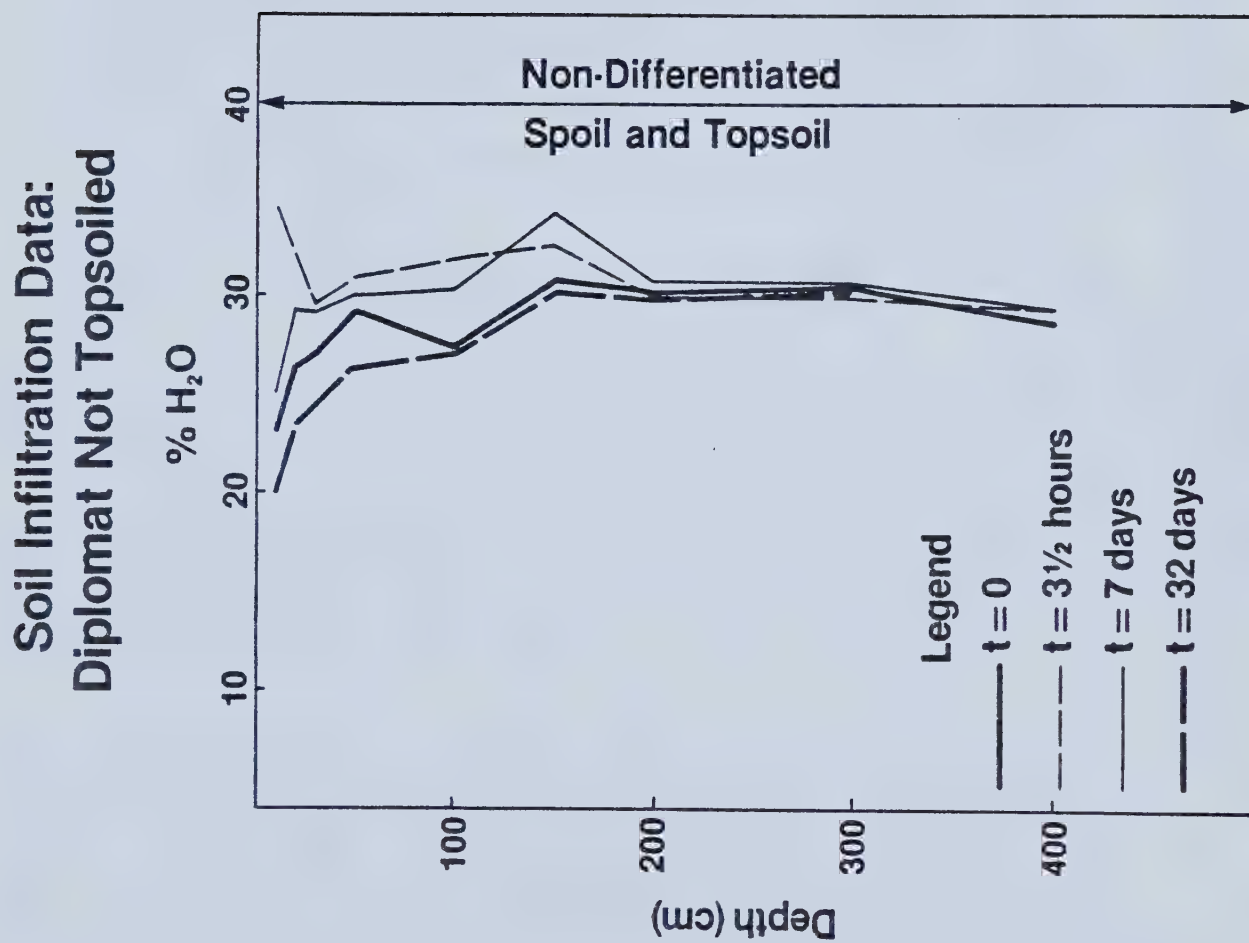


FIGURE 9. Flood test results from 1981.

show that the average rate of water entry is, in fact, lower for site BR 60. The previous flooding had wetted the plot to some degree however, and this served to lower the matric potential gradient and may have reduced the initial infiltration rates.

CONCLUSIONS

Infiltration from temporarily ponded conditions is considered by several authors (Freeze, 1969; Freeze and Banner, 1970; Rehm et al, 1982) to be the primary source of recharge on the prairies. From our simulation of these conditions we propose the following conclusions regarding recharge and soil moisture movement occurring in the study area:

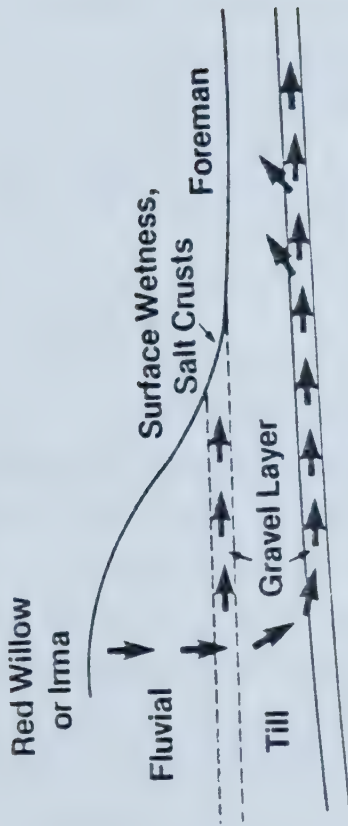
- (a) Those soils of the Irma and Red Willow Series, which have developed on sandy alluvial material overlying till allow a relatively rapid infiltration and downward percolation of water. The till acts as a barrier to further downward movement initially at the contact with the alluvial cap, and subsequently through the numerous coarse-textured layers upon the till, and incorporated within the till. The flow then becomes lateral and forms a perched water table. The Foreman soils, which are located at the base of the alluvial terraces undergo wetting and salinization as a result of this process.

Occurrence of recharge to the perched water tables is probable during periods of heavy rain, or snowmelt on the Irma, Red Willow soils because of their high infiltration rates and their ability to rapidly conduct water through the coarse textured alluvial material. Discharge areas, such as the Foreman soils, also tend to undergo frequent recharge due to the shallow depth of the perched water table combined with the prolonged periods of soil wetness (Freeze and Cherry, 1979). Recharge to deeper aquifers is not significant under Irma and Red Willow soils. It is not known how much, if any, of the discharge from perched aquifers will recharge a larger groundwater system; further analyses of the natural soil moisture data from Foreman soils should aid in answering this question.

- (b) Those soils of the Elnora-Killam-Foreman association undergo similar process as those of the Red Willow-Foreman association and Figure 10 illustrates the hypothetical flow patterns for both associations. Layers of coarse-textured material act as perched aquifers and are responsible for the salinization that has occurred in the Foreman soils and possibly in the Killam. Recharge to a deeper aquifer is unlikely except where perched aquifers discharge. The analysis of data from the mid and lowerslope positions of Site BR 62 may provide information regarding the possibility of recharge from a discharging perched aquifer.
- (c) At site BR 48, recharge is likely to occur, primarily due to movement of water through joints and fissures in the Bnt horizon. Solonetzic Bnt horizons have been traditionally considered "impermeable", however, there is evidence to suggest that, during dry periods, water will infiltrate and flow around the peds, and further into the soil and subsoil.
- (d) In reclaimed areas, recharge is site specific and may occur only where interconnected macropores and cracks allow rapid passage of water to depth. A slower, more uniform type of flow may contribute to recharge but it would depend upon the depth of ponding, initial soil moisture conditions, and evapotranspiration.

All infiltration flood tests were performed during mid summer and late summer, when soil moisture conditions in the top metre were generally dry, and the probabilities for the occurrence of cracks and fissures in the solum would be high. The study therefore represented conditions where infiltration and possible recharge would occur from temporary ponding as a result of a summer storm.

Generalized Flow



Red Willow-Foreman Associations



Elnora-Killam-Foreman Associations

FIGURE 10. Hypothetical flow patterns for Red Willow-Foreman and Elnora-Killam-Foreman soil associations.

FOLLOW UP STUDIES

Information is now needed to represent ponding from spring snowmelt conditions, where the solum is more uniformly moist and the probability of cracks and fissures is low.

In the 1982 season, the study will focus upon two primary objectives. The first is a refinement in data collection at the Battle River study area. This will be accomplished by a more suitable means of plot design, which includes use of a large diameter double ring system which was successfully field tested last autumn. It will also include earlier flooding times, preferably during spring when soil moisture contents are higher, and greater precision in neutron probe calibration by in-situ bulk density measurements with a gamma twin probe system. At present, calibration curves for the sites at Vesta mine are based on soil bulk density data from Diplomat mine land due to insufficient data from sampling at Vesta mine.

The second objective involves an attempt to quantify unsaturated flow. Originally it was hoped that this would be accomplished through identification of the unsaturated hydraulic conductivity relationships to soil moisture. The 1981 data show, however, that in reclaimed lands, tensiometer responses and neutron probe responses to wetting may not always coincide. In reclaimed lands, the presence of a large range of pore sizes appears to result in wetting patterns that are somewhat different than encountered in more "classical" situations. Since prediction of unsaturated hydraulic conductivity involves some knowledge of the relationships between soil matric potential and water content, estimation of recharge using this approach becomes complicated. A more effective means of estimating recharge is to use a mass balance approach, and it is hoped that sufficient data can be acquired in 1982 to begin arriving at recharge estimates.

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PERSONAL COMMUNICATION

Dollhopf, D., Soil Physicist, Montana State University, Bozeman, Montana.

RESEARCH ASSESSING THE RECONSTRUCTION OF SOILS
DISTURBED BY SURFACE MINED COAL IN EAST-CENTRAL ALBERTA

By

A. L. Reid and L. A. Leskiw¹

ABSTRACT

Major difficulties in reclaiming lands disturbed from the surface mining of coal in the plains region of Alberta are caused by the saline/sodic nature of the subsoils and bedrock. The Battle River Reconstruction Project involves four (4) experiments designed to assess methods of reconstructing soil profiles in order to ameliorate the problems caused by the salinity/sodicity.

The experiments assess soil reconstruction methods in terms of (a) varying subsoil depths; (b) separating and mixing subsoil horizons; (c) the use of bottom ash as a capillary barrier to salt movement; (d) altering the surface configuration (slope and aspect) of the reclaimed land; and (e) the use of gypsum and bottom ash as surface amendments. Yields from two cropping systems - cereal/fallow rotation and forage production, and soil salt and moisture movement are being monitored for 5 years. This paper discusses the results from the second growing season of the project.

This year's yields indicate that (a) topsoil gives the greatest advantage for reclamation; (b) increased subsoil depth provides no added advantage for reclamation; (c) bottom ash increases plant establishment over sodic mine spoils but results in a decrease in establishment if applied over topsoil; (d) poor traction on surface applied bottom ash is a major problem; and (e) gypsum applied at 20 T/ha effectively ameliorates the sodium problems that occur in soil reconstruction materials.

There is evidence of salt movement from the spoil to the subsoil in the soil reconstruction depths of 50 to 150 cm. There is evidence that salt is migrating along the subsoil/spoil interface into the lower slope positions of the Slope Drainage Experiment.

The results are complicated by differential subsidence of reconstruction treatments. Subsidence by deeper reconstruction treatments resulted in water ponding after heavy rains, consequently, yields on depressed portions of such plots were adversely affected. Crop yields do not yet reflect trends in salt movement. Yield measurements and soil monitoring will continue to establish long-term trends.

¹Pedology Consultants, Edmonton, Alberta.

INTRODUCTION

Project Objectives

The Battle River Soil Reconstruction Project was initiated in 1979 to determine the most effective methods of reclaiming sodic mine spoil in the Battle River Coal Field of east-central Alberta. The project objectives are:

1. To determine the required depth of soil replacement over sodic mine spoil to ensure that mined land, particularly in the Battle River Coal Field, meets reclamation objectives. In this area, the reclamation objective is to return mined land to former levels of agricultural productivity.
2. To develop methods of sustaining re-established productivity, with emphasis on controlling salt movement from mine spoil into the reconstructed root zone.
3. To develop treatments which will minimize soil quantities needed to restore the original land productivity.

Project Setting

The project is located approximately 20 km north of Halkirk on lands transferred from Manalta Coal Ltd. - Vesta Mine to the County of Paintearth.

The dominant soils of the area before mining ranged from Dark Brown Solonetz to Orthic Dark Brown Chernozems. Climate is described as continental with a frost free period of approximately 100 days and an average annual precipitation between 400 and 450 mm, most of which falls as rain during the growing season.

The research project consists of four experiments constructed on levelled mine spoils. The experiments are:

1. Subsoil Depth
2. Torlea Soil
3. Bottom Ash
4. Slope Drainage

Experimental plots were constructed in 1980 using mine machinery (dozers and scrapers) simulating the "take and put" system of mine reclamation. Details of plot layout are described elsewhere (Parker, 1981).

Crop growth is to be monitored over a five year period. During the first cropping year, 1981, heavy weed infestations resulted in poor crop establishment and failure of a number of forage plots. This paper describes the research of the second, 1982, cropping year. (The first season under the management of Pedology Consultants.)

Acknowledgements

Research activities of the project are funded by the Alberta Heritage Savings Trust Fund, through the Alberta Land Conservation and Reclamation Council, (Plains Coal Reclamation Research Program, PCRRP). Construction of the plots was funded by industry participants; Alberta Power Ltd., Luscar Ltd., and Manalta Coal Ltd. The Soil and Plant Subcommittee of the Alberta Reclamation Research Technical Advisory Committee administers the project.

MATERIALS AND METHODS

Reconstruction Materials

One of the major aspects of reclamation of surface mined lands involves the use of readily available materials for soil reconstruction. Materials assessed for reclamation in this research include (a) topsoil; (b) subsoil excavated prior to mining; (c) sodic mine spoil; and (d) bottom ash accumulated from the coal burning process. Gypsum is used as an amendment in selected treatments. Chemical properties of grab samples collected during plot construction are shown in Table 1.

The topsoil and subsoil materials for the Subsoil Depth, Bottom Ash and Slope Drainage experiments were taken from an area of Orthic Dark Brown Chernozemic and Dark Brown Solodic soils. The soil materials used for the Torlea Soil Experiment originated from Dark Brown Solonchic soils which have significantly poorer chemical characteristics.

Topsoil: Topsoil is loam to clay loam textured A horizon removed from the native soils before mining. It is rated as "fair" topsoil for reclamation based on proposed Alberta Soil Quality Criteria (A.S.A.C., 1981). Salinity is the main limitation; electrical conductivity (EC) values are between 2-4 mS/cm. Topsoil used in the Torlea Soil Experiment has an "unsuitable" rating because of its excessive sodicity (high sodium adsorption ratio, SAR).

Subsoil: Subsoil includes the B and C horizons plus underlying material that has chemical and physical properties suitable for sustaining vegetative growth. The subsoil used was a clay loam textured till which rates "fair to poor" according to the proposed Alberta Soil Quality Criteria. High sodicity and salinity are the major limitations (Table 1). Subsoil materials, consisting of shallow till and weathered bedrock, of the Torlea Soil Experiment are rated "unsuitable" because of high sodicity.

Spoil: Spoil consists of sodic bedrock materials of the Horseshoe Canyon Formation. It is unsuitable reclamation material because it has SAR values above 20 (Table 1). The relatively low EC values in comparison with the SAR values is characteristic of spoil materials of the Northern Great Plains (Power et. al., 1978).

Table 1. Mean Chemical Analysis of Materials used in Plot Construction.

EXPERIMENT	MATERIAL	PH		EC(mS/cm)		SAR		SATURATION %		RECLAMATION SUITABILITY RATING
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	
Subsoil Depth	Topsoil	6.8	0.18	3.6	0.48	3.5	0.77	-	-	F(EC)
	Subsoil	7.8	0.10	5.8	0.67	8.4	1.60	-	-	F-P(EC;SAR)
	Spoil	8.0	0.14	2.9	1.00	23.9	2.73	-	-	U
Bottom Ash	Topsoil	6.8	0.19	3.4	0.72	4.5	2.42	-	-	F(EC;SAR)
	Subsoil	7.6	0.12	5.5	0.86	8.5	2.86	-	-	F-P(EC;SAR)
	Spoil	7.7	0.25	2.7	0.63	22.7	3.60	-	-	U
Slope Drainage	Topsoil	6.8	0.39	3.5	1.49	5.9	4.16	51	3.5	F(EC)
	Subsoil	7.4	0.33	5.8	1.45	12.6	6.61	68	27.1	F-P(SAR)
	Spoil	7.9	0.18	2.8	0.30	24.0	1.67	-	-	U(SAR)
Torlea Soil	Topsoil	7.7	0.10	2.4	1.00	13.5	1.25	71	7.4	U(SAR)
	Subsoil	7.4	0.28	5.7	1.33	14.2	1.65	100	25.5	U(SAR)
	Spoil	7.7	0.21	2.7	0.72	20.2	4.64	163	29.4	U(SAR;Sat.%)
	Ash	7.8	0.23	1.2	0.23	24.5	3.71	-	-	-

Bottom Ash: Bottom Ash is the waste product of coal burnt at the Battle River Thermal Power Station. It is a sandy textured, pumice like material characterized by relatively high calcium content and often toxic concentrations of boron (McCoy et. al., 1981).

Gypsum: Gypsum is applied at 20 Tonnes per hectare (T/ha) as a surface amendment in the Torlea Soil Experiment and below the subsoil of one treatment of the Bottom Ash Experiment.

Crop Husbandry and Yield Determinations

The soil reconstruction treatments are being evaluated in terms of two cropping systems: cereal/fallow rotation and forage production. Neepawa wheat was seeded by press drill on the cereal plots of the Subsoil Depth and Bottom Ash experiments. On plots designated for forage crops a mix of brome grass and alfalfa was seeded with a wheat nurse crop. Seeding and fertilizer rates are shown in Table 2.

The seed bed was prepared by two cultivations and three harrow passes. The crops were seeded in late May. Chemical spray was used to control wild oats and broad leaf weeds.

The forage crop on the Slope Drainage Experiment was harvested in mid-July and early-September. The wheat crop from the cereal plots and wheat nurse crop from the forage plots of the remaining three experiments were harvested in late-September.

Forage yields are expressed on a dry weight basis (kg/ha) calculated from entire plot fresh weights measured in the field and subsamples dried to constant weight. Wheat yields in kg/ha were calculated from plot moist grain yields and subsamples dried for 24 hours at 60 degrees C.

Soil Moisture

Neutron probe access tubing was installed in all plots during seeding operations. A Campbell Scientific Subsoil Moisture Gauge Model #503 was used for monitoring. Measurements were conducted in July, August, and September on three experiments, and in September and October on the Torlea Soil Experiment.

Soil Salinity

The soils in each plot were sampled at 15 cm intervals to at least 50 cm into the underlying spoil. Chemical analyses included pH, electrical conductivity, sodium adsorption ratio, saturation percent, soluble cations (Ca, Mg, Na, K) and soluble anions (SO₄, Cl).

Table 2. Seeding and fertilizer rates.

CROP	VARIETIES	METHOD OF APPLICATION	RATES kg/ha	FERTILIZER RATE (23-24-0) kg/ha
Wheat	Neepawa	press drill at 3-4 cm depth	100	90 (banded)
Forage	Neepawa wheat (as a nurse crop)	press drill at 3-4 cm depth	55	100 (banded)
	Bromegrass (Charlton, certified #1)	seeded with nurse crop using press drill	8	
	Alfalfa (Rambler, certified #1)	seeded on the surface from a grass seed attachment	15	
Established Forage (Slope Drainage Experiment)	Bromegrass (Charlton, certified #1) Alfalfa (Beaver)	Broadcast in 1981	4	90 (press drill)
			16	

RESULTS

Subsoil Depth Experiment

The Subsoil Depth Experiment is designed to evaluate the benefit of varying the depth of subsoil material placed above the sodic mine spoil. Subsoil depth was evaluated in terms of six treatments:

1. 15 cm topsoil over spoil
2. 15 cm topsoil plus 25 cm subsoil over spoil
3. 15 cm topsoil plus 50 cm subsoil over spoil
4. 15 cm topsoil plus 100 cm subsoil over spoil
5. 15 cm topsoil plus 150 cm subsoil over spoil
6. 15 cm topsoil plus 300 cm subsoil over spoil

Yield measurements were made from the wheat crop and wheat nurse crop of the forage plots. No significant difference ($p = 0.05$) in yield occurred between treatments (Figure 1). Dry grain yields from the forage plots average 827 kg/ha and those of the cereal plots average 1256 kg/ha.

Ranking of average yields from both cropping systems shows that shallower subsoil depth treatments yielded higher than the thicker subsoil depths. This trend, not statistically significant, of decreasing yield with increasing subsoil depth is largely attributed to differential subsidence. The deeper treatments which subsided to a greater extent tended to have water ponding after heavy storms. This appears to have negated any benefit that could have resulted from increasing subsoil depth.

The lack of significant effect of subsoil depth on crop yields may be due to the abundant moisture supply during the growing season which would buffer the effects of salt in the soil profiles. There was little variation with soil moisture within or between treatments. The neutron probe readings indicated soil moisture contents consistently between 0.3 and 0.4 grams of water per cubic centimetre of soil.

Since the subsoil materials have the highest salinity values the effect of subsoil depth may not be that dramatic. However, as salt concentration increases, especially as sodium salts move into the subsoil from the spoil, variations in crop yield with subsoil depth may become apparent. There may be movement of sodium salts into the subsoil materials as indicated by increases in soluble sodium and electrical conductivity in the depth intervals above the subsoil/spoil interface. The trend of increasing salinity with proximity to the subsoil/spoil interface was most evident in the reconstruction treatments having 100 and 150 cm of subsoil.

Other research has shown that there is no benefit in increasing soil depth greater than 70 to 100 cm above sodic mine spoil (Power et. al., 1980).

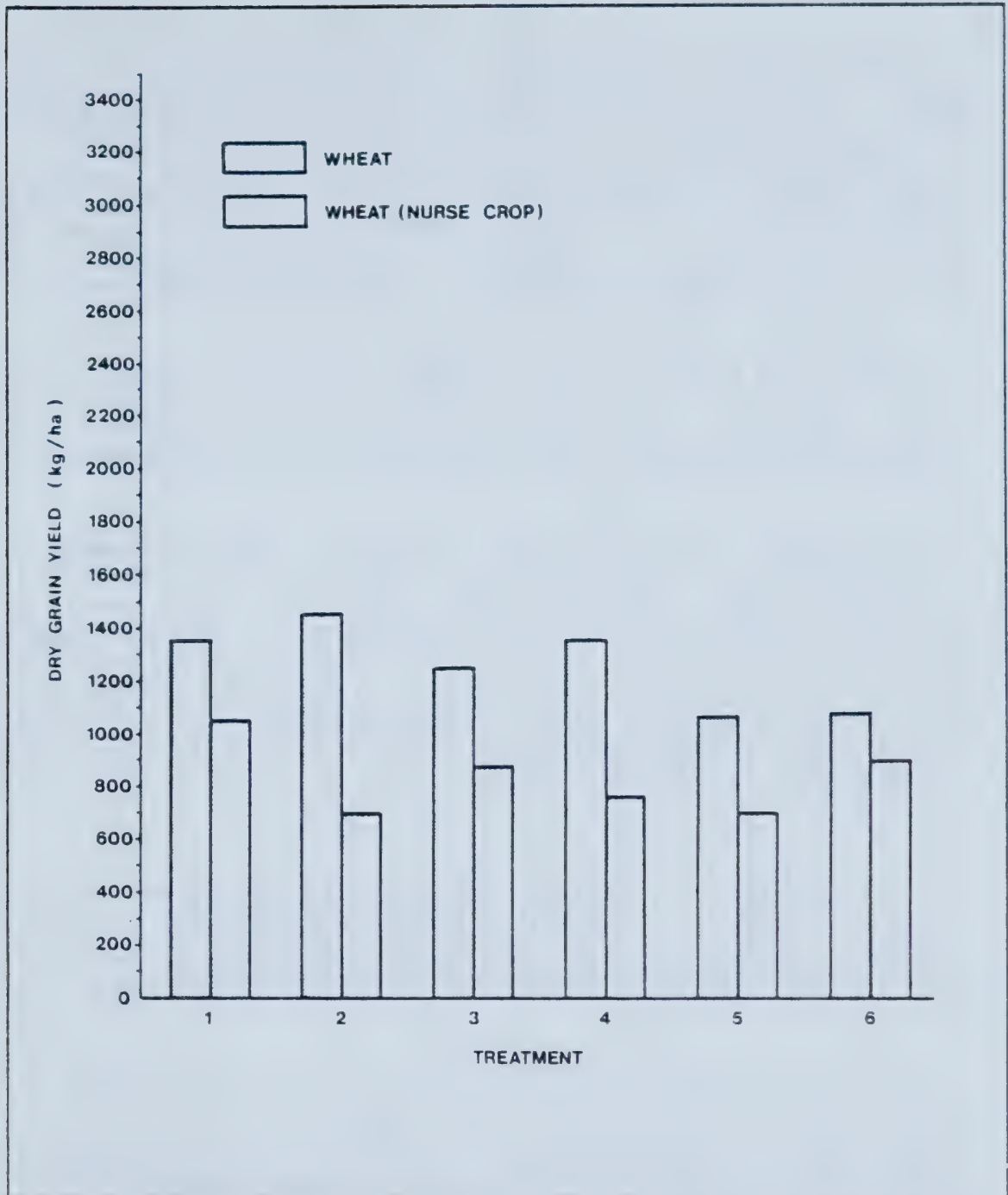


Figure 1. Subsoil Depth Experiment - 1982 yields. There was no significant ($p = 0.05$) yield differences between reconstruction treatments.

Treatment	Soil Reconstruction
1	15 cm topsoil/spoil
2	15 cm topsoil/25 cm subsoil/spoil
3	15 cm topsoil/50 cm subsoil/spoil
4	15 cm topsoil/100 cm subsoil/spoil
5	15 cm topsoil/150 cm subsoil/spoil
6	15 cm topsoil/300 cm subsoil/spoil

Bottom Ash Experiment

This experiment assesses the potential of bottom ash as a capillary barrier to prevent upward movement of sodium salts from the underlying spoil. The relatively high concentrations of exchangeable calcium in the bottom ash make it a potential buffer material (Parker, 1981). Three thicknesses of bottom ash (5 cm - Treatment 3; 15 cm - Treatment 4; and 45 cm - Treatment 5) placed between a "root zone soil" consisting of 15 cm of topsoil plus 25 cm of subsoil and the sodic mine spoil are tested against a control (15 cm topsoil plus 25 cm subsoil over spoil - Treatment 1) and a treatment containing 20 T/ha of gypsum placed between the "root zone soil" and the spoil.

Yields were similar in all treatments (Figure 2). The average dry grain yields on the cereal and forage plots were 697 kg/ha and 580 kg/ha, respectively. The yields are artificially low due to an improper thresher setting, however, the relative yields are consistent with field observations made at harvest.

No apparent interactions have developed within this experiment. Uniform crop yields are reflected by relatively uniform soil moisture and chemical data. Although the ash layer appears to be exerting some influence on soil moisture content, the effect of the ash layers, in this moist growing season, were not great enough to alter crop yields or patterns of salt movement. The lack of significant differences ($p = 0.05$) between treatments is to be expected since the soil root zone depth is constant and the effect of sodium migration is more likely to become evident in subsequent years.

Slope Drainage Experiment

This experiment is designed to determine the effect of landform (slope and aspect) on productivity through its influence on salt movement and accumulation. Plots of 5 and 10 degree slopes are oriented on north and south aspects. Yields are determined for the upper, middle, and lower slope positions.

There are no significant differences ($p = 0.05$) in yields between slope, aspect, and slope position (Figure 3). The highest forage yields, total of the two cuts, (2385 kg dry wt/ha) was on the lower slope position of the plots with 5 degree slope and north aspect. The lowest yield (1260 kg dry wt/ha) was on the lower slope position of the 10 degree slope with a north aspect.

Soil moisture and salinity data indicate that salts are moving into the lower slope positions. The trends are most evident from the SAR data. There is some evidence that the movement is greatest along the subsoil/spoil interface, however, this is not yet fully verified.

The trends of salt and moisture movement were not reflected in crop yields. There is no significant variation in crop yields. The variability of the swards within the plots due to variable weed growth and variations in proportions of grasses and legumes may have been enough to mask any effect on yields that increases in salts may have caused.

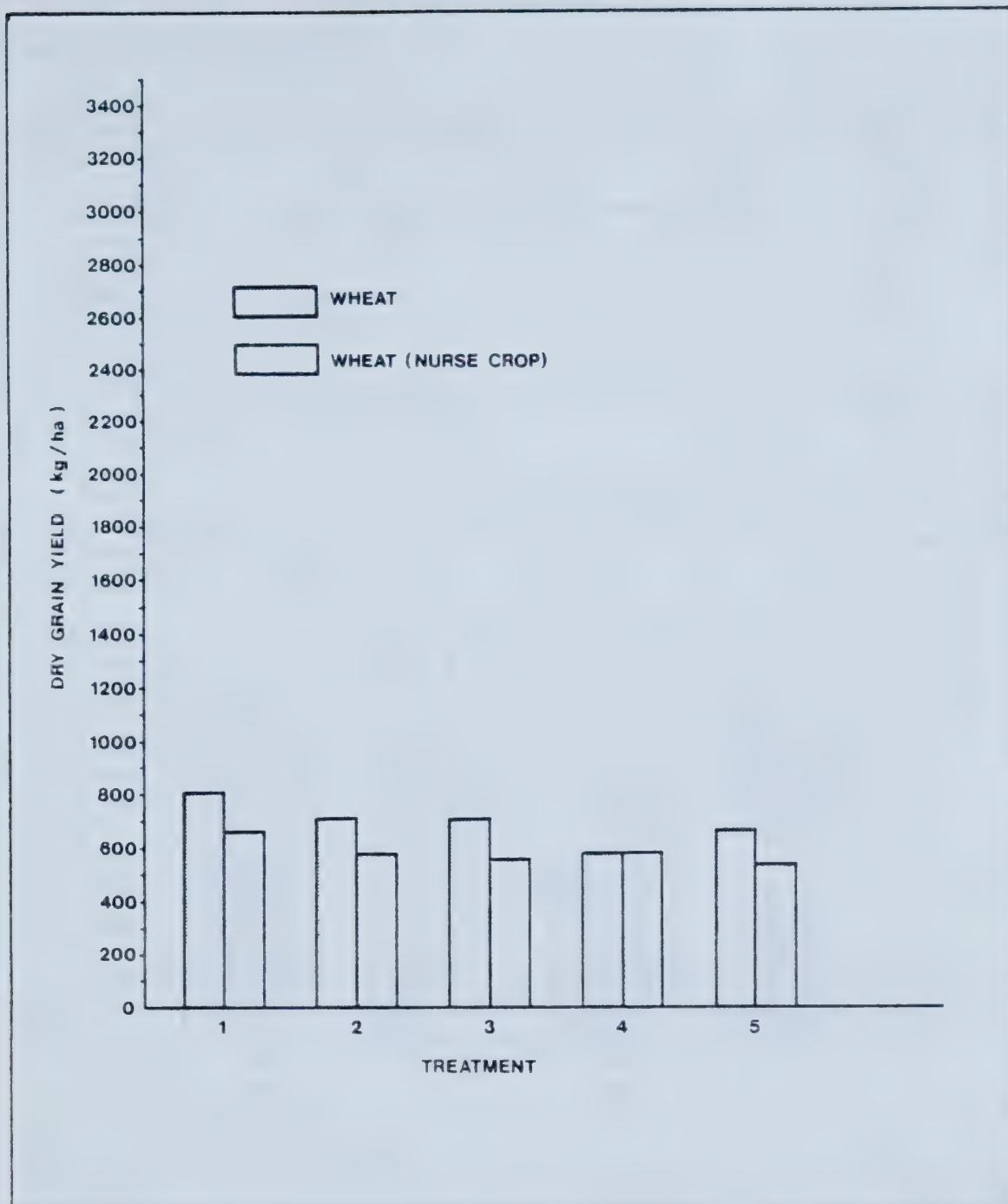


Figure 2. Bottom Ash Experiment - 1982 yields. There was no significant ($p = 0.05$) yield differences between reconstruction treatments.

Treatment	Soil Reconstruction
1	15 cm topsoil/25 cm subsoil/spoil
2	15 cm topsoil/25 cm subsoil/gypsum (20 T/ha)/spoil
3	15 cm topsoil/25 cm subsoil/5 cm bottom ash/spoil
4	15 cm topsoil/25 cm subsoil/15 cm bottom ash/spoil
5	15 cm topsoil/25 cm subsoil/45 cm bottom ash/spoil

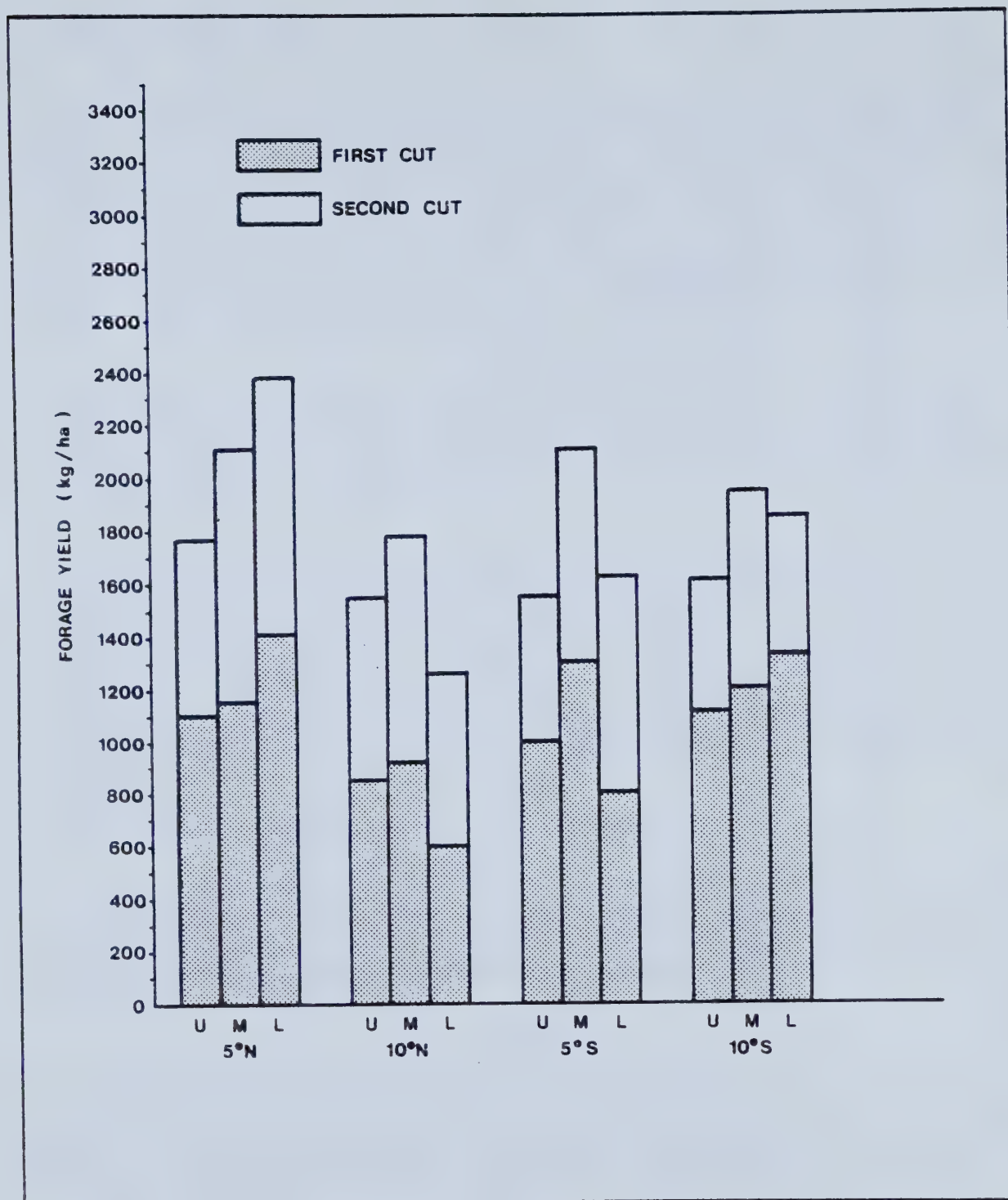


Figure 3. Slope Drainage Experiment - 1982 yields. U, M, and L signify upper, middle, and lower slopes, respectively. There were no significant ($p = 0.05$) yield differences.

Torlea Soil Experiment

The Torlea soil, a Dark Brown Solonetz, has a thin A horizon and hard sodic Bnt horizon rendering it as suitable only for perennial forage crops unless costly land preparation procedures are employed.

There are several possible methods of ameliorating the sodic nature of these soils. These include:

1. Removal of the sodium enriched B horizon.
2. Mix the B horizon with the calcium enriched upper C horizon.
3. Apply gypsum.
4. Apply calcium rich bottom ash. A 15 cm layer of bottom ash contains exchangeable calcium approximately equivalent to a 20 T/ha application of gypsum (Parker, 1981).

The Torlea Soil Experiment tests these methods of ameliorating the sodic nature of the topsoil and subsoil materials which are rated "unsuitable" for reclamation (Table 1). Seven soil reconstruction treatments are compared:

- Treatment 1: Spoil to the surface (no soil materials)
- Treatment 2: 10 cm A horizon - spoil
- Treatment 3: 10 cm A horizon - 20 cm B plus upper C horizon - spoil
- Treatment 4: 10 cm A horizon - 45 cm B plus upper C horizon - spoil
- Treatment 5: 10 cm A horizon - 75 cm C horizon - spoil
- Treatment 6: 10 cm A horizon - 100 cm B plus C horizons - spoil
- Treatment 7: 10 cm A horizon - 45 cm C horizon - 20 cm Ash - spoil

Surface amendments of 15 cm bottom ash and gypsum at 20 T/ha are compared with a control (no amendment) as split plots of the soil reconstruction treatments.

Forages were seeded on these plots and the wheat nurse crop was harvested this year. The most dramatic differences in yields occurred on these plots. The effects on yield could be attributed to both soil reconstruction treatments and to surface amendments ($p = 0.05$).

Soil Reconstruction: The most significant gain in productivity results from the application of topsoil over spoil - average yield of the three subplots increased from 173 kg/ha to 845 kg/ha (treatments 1 and 2, respectively) (Figure 4). Only treatments 4 and 5 yielded significantly higher than the other treatments where subsoil materials were used. Treatment 5 had the highest average yield (1343 kg/ha).

The increase in yield for treatments 4 and 5 cannot be fully attributed to subsoil depth or horizon mixing. Treatment 4 contained 45 cm of mixed B plus upper C horizon while Treatment 5 contained 75 cm of C horizon. Crop growth of Treatment 6 (100 cm of B plus C horizon) was hampered by subsidence and water ponding. One would expect this treatment to be equal to or better than Treatment 4 or 5.

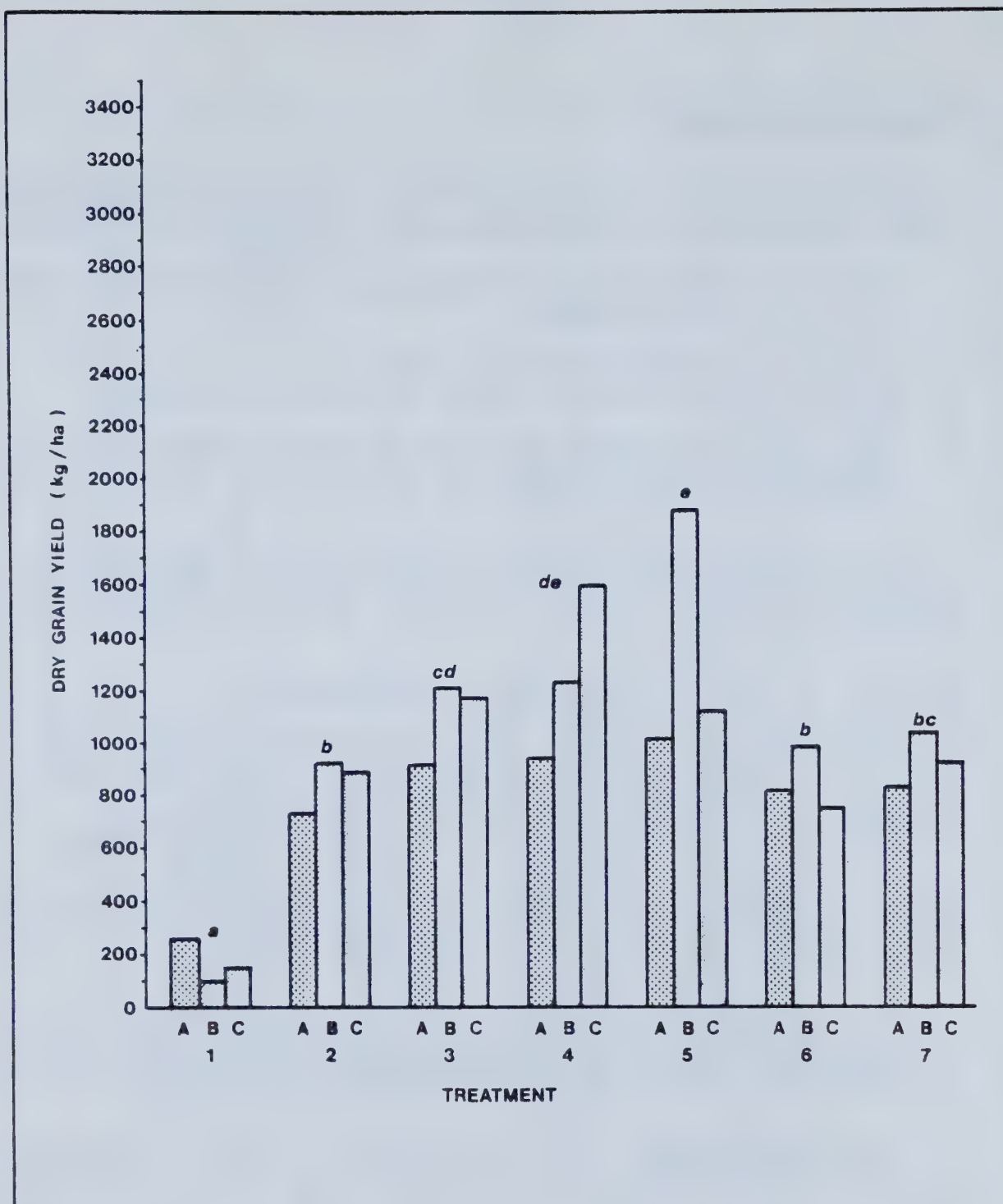


Figure 4. Torlea Soil Experiment - 1982 yields. A, B, and C respectively signify surface amendments of 15 cm of Ash, 20 T/ha gypsum and a control. Different letters above histogram show significant difference ($p = 0.05$) between reconstruction treatments.

Treatment	Soil Reconstruction
1	Spoil
2	10 cm topsoil/spoil
3	10 cm topsoil/20 cm B and upper C horizons/spoil
4	10 cm topsoil/45 cm B and upper C horizons/spoil
5	10 cm topsoil/75 cm C horizon/spoil
6	10 cm topsoil/100 cm B and C horizons/spoil
7	10 cm topsoil/45 cm C horizon/20 cm Ash/spoil

Soluble sodium content increases with proximity to the subsoil/spoil interface in treatments 3, 4, and 5 indicating that sodium may be migrating into the root zone of these treatments. The increases of soluble sodium in the subsoil near the subsoil/spoil interface is consistent with the increases shown in the intermediate subsoil depths of the Subsoil Depth Experiment.

The advantage of adding soil materials over spoil appears to be one of improved physical characteristics resulting from a reduction of surface SAR and saturation percent. EC and sodium content is fairly uniform between materials.

Surface Amendment: Bottom ash provided a more suitable medium for crop growth than spoil materials alone (Figure 4 - Treatment 1). However, where the soil materials were used in reclamation the addition of bottom ash had negative effects. These negative effects could largely be attributed to the traction problems encountered on these materials. During seeding, machinery rutted the ash resulting in variable seeding depth and inconsistent germination. Shaneman and Logan (1978), and Natsukoshi (1981) have also documented such problems.

The application of gypsum resulted in increased yields in all but treatments 1 and 4. The most dramatic increase in yield occurred in Treatment 5 where the subplot with gypsum applied had an average yield of 1888 kg/ha, the highest yield of all plots within the compound. This yield is close to the long term average Neepawa wheat yield of 2000 kg/ha for the Forestburg area. The effect of gypsum appears to be improved physical and chemical properties. Gypsum exerted the most significant influence on SAR by dramatically improving the calcium to sodium ratio. The saturation percent was slightly reduced in surface samples where gypsum was applied. The salinity of the surface samples where gypsum was applied increased significantly ($p = 0.05$).

The soil moisture influence was not marked. Excess surface moisture in Treatment 6, which has subsided, resulted in reduced yields. Only treatments 3, 4 and 5 had expected moisture profiles. These treatments which had a reduction in soil moisture with decreasing depth and were those treatments which showed possible salt movement across the subsoil/spoil interface. No trends of salt movement were significant.

The relative yield of the wheat nurse crop does not reflect the growth of the forage crop. Some plots which were low yielding had a good "catch" of alfalfa. This was especially true on those plots where the bottom ash was added as a surface amendment.

SUMMARY

Crop Yields

Soil reconstruction treatment caused no effect on crop yields within the Subsoil Depth, Bottom Ash and Slope Drainage experiments. The lack of yield variation in these experiments could also be explained by:

- a. lack of major salt movement to date;
- b. insignificant differences in chemical properties of the subsoil and spoil which would affect crops;
- c. enough moisture throughout the growing season to buffer soil salinity;
- d. random variation in crop growth (Slope Drainage Experiment);
- e. differential subsidence (Subsoil Depth Experiment); and
- f. poor threshing (Bottom Ash Experiment).

The Torlea Soil Experiment had significant variation in yields with soil reconstruction treatment and surface amendment. The variations were due to:

- a. beneficial affects of topsoil materials over the spoil;
- b. improved crop establishment on bottom ash applied over spoil;
- c. the detrimental effect of bottom ash applied over soil materials;
and
- d. increased yields due to the effects of gypsum applied as a surface amendment.

The lack of randomization within this experiment weakens these interpretations.

Soil Moisture

Soil moisture measurements showed little variation with treatment, date of measurement or depth. This lack of variation causes concern of the sensitivity of the neutron probe. Interpretations of the readings immediately after the first measurement in 1983 coupled with correlation to gravimetric moisture and bulk density data are required to test the probe.

Soil moisture measurements did indicate increased moisture in the soil materials of the lower slope positions in the Slope Drainage Experiment and less moisture content in the thick ash layers of the Bottom Ash Experiment. Both trends were expected.

Soil Chemistry

There is evidence of salt movement from the spoil to the subsoil in the intermediate depths of the Subsoil Depth and Torlea Soil experiments. Salt is migrating to the lower slope positions of the Slope Drainage Experiment. The movement of salts is primarily along the subsoil/spoil interface of the Slope Drainage plots. The movement of salts has not been severe enough to result in a reduction in crop yield within these experiments. As the monitoring program continues, the effects of salt movement should become more dramatic.

Interactions

Crop x reconstruction interactions occurred in the Torlea Soil Experiment only. Salt movement x reconstruction treatment interactions were evident in the intermediate depth treatments of the Torlea Soil and Subsoil Depth experiments where salt moved across the subsoil/spoil interface. Movement along the subsoil/spoil interface has resulted in increased salt content of the lower slope positions in the Slope Drainage Experiment.

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RECLAMATION ACTIVITIES IN ALBERTA
BY CROWS NEST RESOURCES LIMITED

By

Eugene W. Fabro¹
Dean Kittleson²

ABSTRACT

Crows Nest Resources Limited is a wholly-owned subsidiary of Shell Canada Resources Limited and was formed to manage and develop the consolidated coal holdings of Shell and Crows Nest Industries.

Crows Nest Resources Limited's corporate philosophy is based on establishing profitable coal mining operations that are environmentally and socially acceptable. This paper outlines the organization's developing approach to environmental matters using brief reviews of Alberta reclamation projects as examples.

¹ Supervisor, Environmental Planning, Crows Nest Resources Limited
² Environmental Planner, CNRL

Introduction

Crows Nest Resources Limited (CNRL), formed as a subsidiary of Shell Canada Resources Limited (SCRL) in December, 1978, is responsible for the management and development of coal holdings totalling some 393,000 hectares. These holdings are located in Saskatchewan, Alberta and British Columbia and include the operating Line Creek Mine 20 kilometers north of Sparwood, B.C.

The responsibility for CNRL's environmental and regulatory affairs is divided between the Line Creek office, responsible for reclamation and environmental research at the mine site and on adjacent B.C. properties and the Calgary office, responsible for environmental concerns on all other project areas.

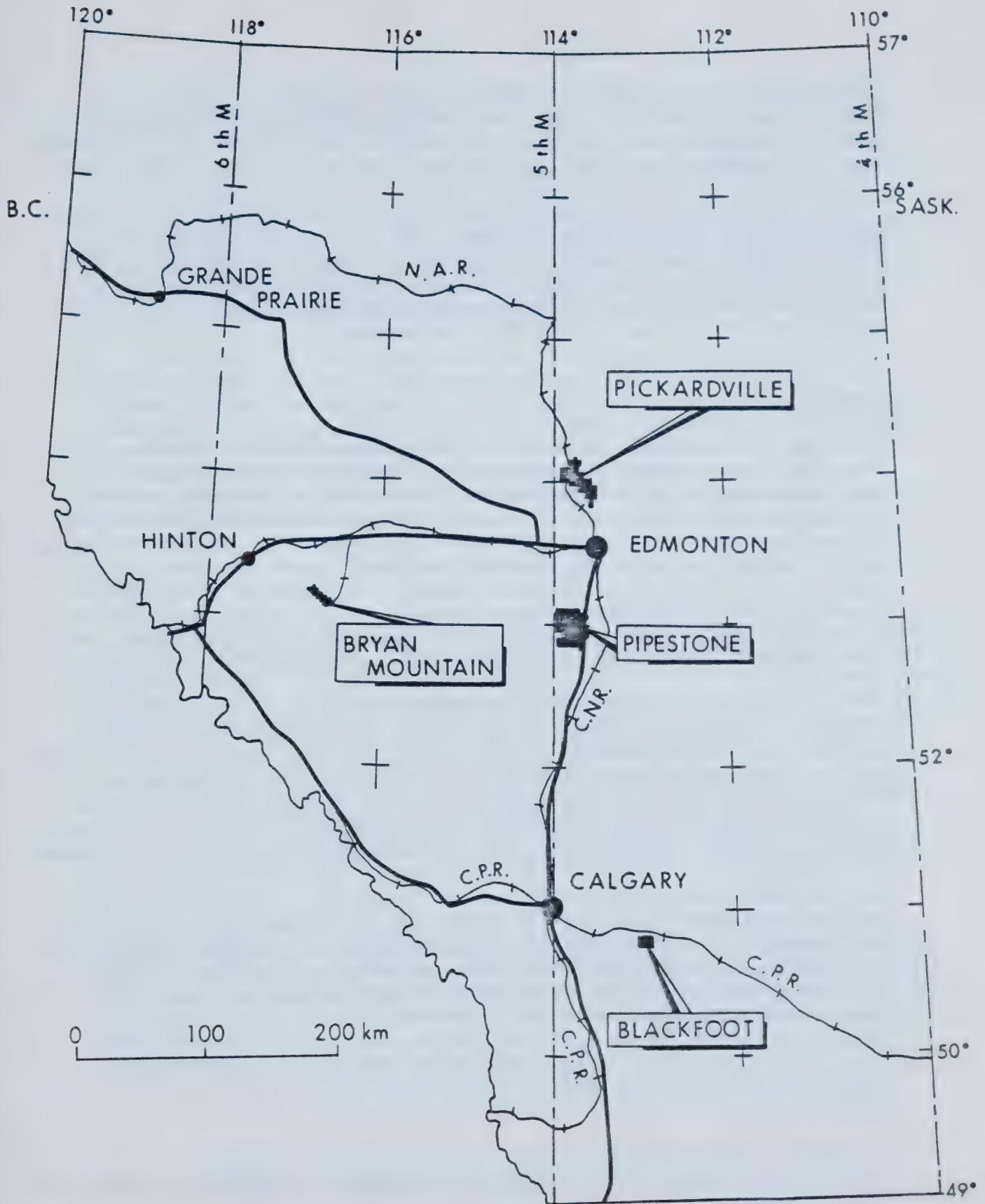
The purpose of this paper is to review reclamation projects undertaken by SCRL/CNRL in Alberta and demonstrate that the company's commitment to sound environmental planning has been built upon knowledge gained from these reclamation experiences. The information gained in the early projects has been used in successive reclamation tests with meaningful results produced, that were and will continue to be integrated into development and operational planning while meeting the needs of government and the general public. The four properties to be reviewed are Pickardville, Pipestone, Blackfoot and Bryan Mountain.

Pickardville

The Pickardville coal property is located 65 kilometers northwest of Edmonton. In 1976 the property was the subject of SCRL evaluations in anticipation of a preliminary disclosure being submitted to government. The document was prepared but not submitted due to the company's internal assessment that insufficient guarantees existed to ensure a successful return of agricultural productivity levels as required under the newly enacted 1976 Alberta Coal Development Policy. Subsequently in 1977, as a result of consultations with the government and local residents, SCRL (in joint-venture with PanCanadian Petroleum Limited) conducted a reclamation program on a nine hectare parcel of mined out land operated by the Pickardville Coal Company. The primary objective was to demonstrate reclamation capability of disturbed mine spoil.

In 1977-78 using results of an analysis of the mine spoil as well as existing Alberta Soil Survey Reports¹ a simplified ranking of the available materials was carried out. These materials were then selectively levelled and recontoured. After the limited supply of topsoil was replaced the nine hectares were fertilized and seeded with a mixture of grasses and legumes (alfalfa) in 1979. Initially the forage crop was poor, primarily due to inhibited alfalfa emergence attributed to the high clay content of the

¹ Alberta Soil Survey Reports, No. 21, Edmonton and No. 29, Tawatinaw



MAJOR ALBERTA PROJECTS

levelled mine spoil and an insufficient topsoil supply. Heavy weed growth also hindered the crop. Work between 1979 and 1981 was directed toward eliminating soil crusting and weeds to help establish a successful crop. At present there is a fair forage crop with limited weed growth.

The Pickardville reclamation test cannot be documented as a complete success due to materials limitations. The lack of sufficient topsoil salvage and the use of poor quality subsoil components are the primary limitations. The value of the project was the experience gained in practical operating aspects of mine site reclamation and above all the need for a detailed soil survey prior to reclamation.

Pipestone

The Pipestone coal property is located 60 kilometers southwest of Edmonton. The project was the subject of a 1976 SCRL Preliminary Disclosure for new mine development. This SCRL (in joint-venture with PanCanadian Petroleum Limited) proposal did not receive endorsement due in part to reclamation uncertainties. As a result of these uncertainties and in conjunction with the ongoing commitment to reclamation planning and research, SCRL, in 1978, established a "mining-scale" reclamation research plot on the proposed minesite area. The project objective was to simulate an open pit mining operation and return the disturbed land to levels equal to or better than pre-mining agricultural productivity.

At the time of the project government concerns centered around reclamation success of the more productive agricultural lands found in the province. SCRL was able to outline an area using results of a limited soil and overburden survey. From this area the company selected an 18 hectare parcel of land within which a 335 m x 30 m ($\approx$ 1 ha) test plot site was chosen for a 12-meter deep excavation pit. Topsoil and subsoil units, to a total combined depth of one meter, were selectively stripped and stockpiled by scrapers. The remaining 11 meters of material was spoiled within the excavated pit using a dragline. No coal or coaly material was encountered in this 11 meters. The mine spoil was levelled and compacted in preparation for final soil reconstruction. The topsoil and subsoil components were then replaced and during 1978 and 1979 an alfalfa/bromegrass mixture was planted on the full 18 hectare parcel with a fertilizing program also being conducted.

Prior to the 1980 harvest data being analyzed, certain design deficiencies required mitigation. Additional soils investigations were carried out to:

- identify and map the soil types of the 18 hectare parcel;
- identify the exact boundaries of the reclamation test plot as they were not marked;
- provide necessary data to select two sites within the 18 hectare parcel for use as comparison plots.

Without the use of these comparison plots, harvest yields from the test plot would be of little value.

Hay yields were obtained for 1980 and 1981 by analyzing ten 1 m² replicate samples from each plot. Results, averaged for the two years, ranged from 8500 kg/ha to 9500 kg/ha for the three plots, with the test plot yielding 9200 kg/ha. These figures were above the 1975-79 average yeild of 4300 kg/ha for the surrounding Agriculture Reporting Area No. 5² indicating the soils found in the test site area are of high quality and may not be representative of the whole property.

The Pipestone project as completed, provided adequate results on materials handling, soil reconstruction and vegetative regrowth. Part of this success can be directly attributed to the availability and use of high quality soils in the project area. Additional research is required to provide data on reclamation success using intermediate or low-quality soils in the area, different soil reconstructions and actual coal mine spoil. Similar to Pickardville, valuable practical experience was gained in reclamation procedures.

Blackfoot

The Blackfoot coal property located 95 kilometers southeast of Calgary is part of the Blackfoot Indian Reserve No. 146. SCRL/CNRL began evaluating the coal resources of the property in 1977 and by 1979 had determined there was potential for mine development. Having learned from earlier experiences CNRL proposed a number of studies to begin the establishment of a sound environmental data base for use in future stages of development planning.

The first study undertaken in 1979 was a detailed soil and overburden survey with interpretations for reclamation. A second study using recommendations of the soil survey was designed in 1979-80, to test the reclamation capabilities of the dominant soil groups using demonstration plots.

The objective of the detailed soil survey and overburden characterization study was to identify and map the materials found on the property. This information, comprised of physical and chemical properties, occurrence, depth and thickness was used to evaluate soil capabilities for agriculture, irrigation and revegetation. The results of these evaluations defined the three dominant soil groups on the property and gave them fair to good capability ratings.

²Alberta Agriculture, Agricultural Statistics Yearbook 1979, 1978, 1977, 1976.

Using results of the soil survey a field reclamation study was established to assure government and local administrations that "equal to or better than" pre-mining productivity levels could be met. Three plots were selected to represent the 3 main soil groups. Each plot was divided into three subplots or treatments measuring 100 m x 15 m. One treatment was used as control only and involved surface rototilling. The other two treatments tested materials handling and soil reconstruction through simulated mining to a three-meter depth. Topsoil and subsoil units, to a combined depth of 1/2 meter, were separately stripped and stockpiled by scrapers. The remaining 2-1/2 meters of overburden was mass-spoiled by backhoe. Various combinations for reconstruction were used involving:

- mass spoil of overburden;
- topsoil salvage with mass spoil of overburden; and
- topsoil and subsoil salvage with mass spoil of overburden.

After completion of the materials handling, 2/3 of each treatment was seeded with wheat owing to its responsiveness to soil variation. The remaining 1/3 of each treatment was seeded with a grass/legume mixture for productivity comparison with native range species.

Harvest yields have been determined for wheat since 1980. The sampling procedure involved twenty-four random sample blocks in which the wheat was clipped, labelled, air dried and then thrashed using a stationary thrasher unit. Weights were determined for "grain and straw" and "grain only" and subjected to statistical analysis. The results indicate those treatments with topsoil and/or subsoil salvage have higher yields. To be statistically valid, however, additional harvest yields are required. To date no data on forage yields have been collected.

In summary, the Blackfoot project does have a design limitation. Actual mine activity will encounter a greater variety of mine spoil including coal or coaly material which will affect ultimate soil profiles. Additional research is required. The existing reclamation activities, however, have produced successful results of materials handling, reconstruction of various soil profiles and vegetative regrowth. Initial hay yields indicate a successful return equal to or greater than pre-mining levels. Through continued plot management, sufficient data will be generated to provide statistically valid conclusions on productivity levels.

Bryan Mountain

The Bryan Mountain coal property is located 50 kilometers southeast of Hinton in the Alberta Foothills region. The property was acquired by CNRL in 1981 with the intention of developing and exporting the high quality thermal coal. The two provincial policies³ governing the area allow full exploration and development subject to compliance with normal approval procedures. To prepare and satisfy the requirements for CNRL's preliminary disclosure and establish a sound environmental data base for future stages the following studies were integrated into the Bryan Mountain development plan:

- preliminary inventory of existing environmental data for the project area;
- biophysical overview;
- soil survey, overburden characterization and interpretations for reclamation;
- construction of reclamation test plots.

The first two studies did not relate directly to the reclamation activities on Bryan Mountain but did provide preliminary assessment on land use capabilities and any potential development impacts. Using the results of these studies CNRL determined post-mining land use would most likely be commercial forestry and wildlife habitat. To establish a base on which an effective reclamation plan could be developed CNRL proposed the latter two studies.

The objective of the soil survey and overburden characterization was to identify existing soils and overburden; once identified, the results could be used to evaluate the reclamation capabilities of the materials. The study identified organic surface soils (comprised of slash, muskeg and peat bogs) and overburden (comprised of till material) as the dominant components. CNRL determined through laboratory analysis that these materials, used individually, would be of poor suitability for successful reclamation. However, because of the variations in physical and chemical properties and the available quantities of each, several favourable soil profile reconstruction options could be considered. CNRL proposed a reclamation test plot study to examine the available options and, assuming commercial forestry as the dominant post-mining land use, the success of reforestation.

The objective of the reclamation test plot study, therefore, was to test successful soil reconstruction and reforestation and assure government agencies and local commercial forestry companies that productivity could be achieved to levels equal to or better than pre-mining levels, as required by the Coal Development Policy.

³The Coal Development Policy; and A Policy for Resource Management in the Eastern Slopes.

In CNRL's continuing approach to integrated development planning, the test plots were constructed in conjunction with the excavation and bulk sampling of two coal test pits in early 1982.

The project design was the same for the two 30 m x 30 m plots. The first step involved the stripping and stockpiling of the first 15 cm of topsoil or organic layer. The subsoil units, comprised of "clean till" or "coaly till" were then stripped to a depth of two meters, segregated and stockpiled separately. The remainder of the overburden material and bedrock were mass spoiled together. After sampling the coal, the mass spoil material was returned to the pit, levelled and compacted. The subsoil units were then replaced in six 5 m x 30 m subplots, alternating between a "clean till" unit and a "coaly till" unit thereby establishing three replicates for each soil profile option used. The final step was spreading the salvaged topsoil evenly across each plot until all subplots were covered.

After replacing the topsoil in June, 1982, the test plots were planted with the two principal commercial timber species, lodgepole pine and white spruce. Each subplot consisted of three rows of alternating species' seedlings totalling 25 per row. A total of 900 seedlings were planted on soils which were disturbed and reclaimed. An additional 100 seedlings were planted in two undisturbed reference plots, each located in proximity to the test plots.

Monitoring of the test plots will involve periodic soil sampling and water table observations for each replicate and reference plot. Annual growth and survival rates will be calculated twice a year; results will be modelled statistically to compare each of the subplots within each plot. To date no analyses are available, however, the survival rate as of October, 1982, was 100%.

In summary, environmental and reclamation activities conducted on Bryan Mountain have produced a sound environmental data base from which successful reclamation operations can be incorporated into a full development plan. Actual results have shown that materials can be handled successfully, soil profiles can be reconstructed and initial reforestation operations are possible and to date are successful. There remains a need for additional, more detailed data to ensure the rehabilitation of Bryan Mountain to land use levels that complement the government's and the general public's demands and expectations.

The conclusions drawn from these reviews indicate the need for detailed environmental studies to be carried out in the early stages of development. These studies involve:

- land use evaluations;
- detailed soils and overburden surveys;
- materials handling and soil profile reconstruction procedures; and
- the testing of productivity levels of disturbed lands.

This paper has endeavored to demonstrate CNRL's progression from a simple revegetation program at Pickardville through to an integrated development project at Bryan Mountain incorporating detailed environmental studies. CNRL, using results from these past experiences as well as future projects, will continue in its on-going commitment to develop sound environmental and reclamation standards.

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- A Policy for Resource Management of the Eastern Slopes, Alberta Energy and Natural Resources, Resource Information Services, 9915 - 108 Street, Edmonton, Alberta, T5K 2C9.

GENERAL AGENDA

WEDNESDAY, FEBRUARY 23

SECOND ANNUAL
ALBERTA RECLAMATION CONFERENCE

FEBRUARY 23 - 24, 1983

Sponsored by:

Alberta Chapter, Canadian Land
Reclamation Association

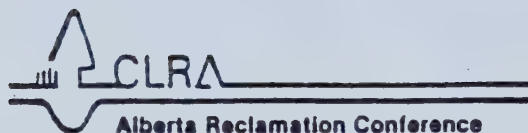
The Coal Association of Canada

Oil Sands Environmental Study Group

Alberta Land Conservation and
Reclamation Council

Canadian Petroleum Association

Convention Inn South
4404 Calgary Trail
Edmonton, Alberta



0730 - Registration - Foyer

0930 - Reclamation Session 1 - Royal Room
Perspectives on Policy
Welcoming Address

1200 - Joint Luncheon with Alberta Soil
Science Workshop - Empire Room

1230 - Business Meeting of the Alberta Soil
Science Workshop

1300 - Luncheon Address - Hon. F. Bradley,
Minister of Environment

1320 Reclamation Session 2 - Royal Room
Joint Session with Alberta Soil
Science Workshop

1700 - Social Hour - Empire Room

1900 - Alberta Reclamation Conference Banquet
- Empire Room

2000 - Banquet Address - Dr. A. Olson,
Assistant Deputy Minister, Research
and Resource Development, Alberta
Agriculture

THURSDAY, FEBRUARY 24

0830 - Reclamation Session 3 - North Ballroom
Pipelines, Oil Sands

1200 - Alberta Reclamation Conference
Luncheon - Empire Room

1300 - Reclamation Session 4 - North Ballroom
Coal Mines, Salinity

1630 - Adjournment

**Wednesday, February 23 - Reclamation Session 1
Royal Room**

- 0930 Opening Comments - M. Ross. Chairman,
Conference Organizing Committee.
- 0935 Chairman's Remarks - Dr. R. Wallace.
Chairman, Oil Sands Environmental Study
Group.
- 0940 Welcoming Address - R. Frocklage.
Canadian Petroleum Association.
- 0955 Organizational Structure and Role of the
Land Conservation and Reclamation Council.
J. King. Chairman, Alberta Land
Conservation and Reclamation Council,
Alberta Environment.
- 1015 Reclamation Research - Priorities and
Programs.
P. Ziemkiewicz. Chairman, Reclamation
Research Technical Advisory Committee,
Alberta Energy and Natural Resources.
- 1035 Coffee - Empire Room
- 1055 The Development and Reclamation Review
Procedure: Changes and New Directions.
L. Brocke. Chairman, Development and
Reclamation Review Committee, Alberta
Environment.
- 1115 The Function and Responsibility of the
Regulated Operations Branch of Alberta
Environment.
D. Bratton. Regulated Operations Branch,
Alberta Environment.
- 1135 Developing Responsible and Practical
Reclamation Legislation in Alberta.
P. Lulman. Canadian Land Reclamation
Association "ex officio".
- 1155 Adjourn to lunch - Empire Room

**Wednesday, February 23 - Reclamation Session 2
Joint Session with Alberta Soil Science Workshop
Royal Room**

- 1320 Chairman's Remarks - J. C. Hermans.
Alberta Agriculture.
- 1330 Keynote Address - M. Ross. Crows Nest
Resources Ltd.
- 1350 The Impacts of Pipelines on Agricultural
Lands in Alberta.
L.C. Marciak, J.C. Hermans. Alberta
Agriculture.
- 1410 Soil Handling Aspects of Coal
Reclamation on Agricultural Lands.
R.J. Logan. Luscar Limited.
- 1430 Weathering Characteristics of Fly-Ash
and Their Implications to Soil
Amendments.
C.J. Warren, M.J. Dudas. University of
Alberta.
- 1450 The Role and Responsibility of the Soil
Scientist in Reclamation of Forested
Environments.
K. Crane. Luscar Limited.
- 1510 Coffee - Empire Room
- 1540 A Review and Evaluation of Drainage on
Agricultural Lands in Alberta.
D.W. Broadfoot. Stanley Associates
Engineering.
- 1600 Mechanical and Vegetative Control of
Dryland Saline Seeps.
H.S. Vander Pluym. Alberta Agriculture.
- 1620 Reclamation of Sodic Spoil; A Physical
and Chemical Approach.
S. Landsburg. Alberta Environment.
- 1640 Closing Remarks - J.C. Hermans.
Alberta Agriculture.
- 1700 Social Hour - Empire Room
- 1900 Alberta Reclamation Conference Banquet
- Empire Room

Thursday, February 24 - Reclamation Session 3
North Ballroom

- 0830 Chairman's Remarks - Dr. R.J. Fessenden.
Director, Soil Survey Division. Alberta
Research Council.
- 0840 Evaluation of Pipeline Reclamation Prac-
tices on Agricultural Lands In Alberta.
W.J. Hastie, H.E. Martens, D.L. Johnson,
C.G. Heath. Hardy Associates (1978) Ltd.
- 0900 Evaluation of the Winter Topsoil Strip-
ping Machine on NOVA Pipelines.
D.G. Paton and A.W. Fedkenheuer. NOVA,
AN ALBERTA CORPORATION.
- 0920 Effect of Topsoil Replacement on Sand
Stabilization and Revegetation In the
Great Sand Hills of Saskatchewan.
D.G. Walker. Walker and Associates Ltd.
D.G. Paton. NOVA, AN ALBERTA
CORPORATION. J. Ashworth. Norwest Soil
Research Ltd.
- 0940 Reclamation of Wellsites and Access Roads
In an Agricultural Environment.
W. McNary. Voyager Petroleums Ltd.
- 1000 Coffee - Empire Room
- 1030 Reclamation Research on Syncrude's
Tailings Dyke.
T.S. Dai, M. Fung, K.P. McCumber,
S.A. McKinnon. Syncrude Canada Ltd.
- 1050 Plant Growth and Mycorrhizal Potential
of Overburdens to be Considered for Use
In the Reclamation of Extracted Oil Sands.
R.M. Danielson, S. Visser, D. Parkinson,
University of Calgary.
- 1110 Testing of Seed Pre-Germination Treat-
ments for Four "Rosaceae" Native to
Alberta.
P. King. Alberta Forest Service.
G. Grainger, A. Straka. Alberta Tree
Nursery and Horticulture Centre.
- 1130 An Integrated Approach to Land
Capability Assessment.
L. Knapik. Pedocan Land Evaluation Ltd.
D.A. Westworth. D.A. Westworth and
Associates Ltd. A.W. Fedkenheuer. NOVA,
AN ALBERTA CORPORATION. S. Stephanson.
Canstar Oil Sands Ltd.
- 1150 Adjourn to Lunch - Empire Room

Thursday, February 24 - Reclamation Session 4
North Ballroom

- 1300 Chairman's Remarks - Dr. W.B. McGill.
Chairman. Soil Science Department.
University of Alberta.
- 1310 Tolerance of Feather Mosses to Brine
Spills.
B. Ross, G.R. Webster. University of
Alberta.
- 1350 Prediction of Groundwater Chemistry In
Reclaimed Landscapes.
M. Trudell, A. Maslowski, E. Wallick,
S.R. Moran. Alberta Research Council.
- 1410 Numerical Modelling of Groundwater
Systems and Prediction of Salinization
Potential.
P. Fransham. Borealis Exploration Ltd.
- 1430 Coffee - North Ballroom
- 1500 Soil Moisture Movement Studies on
Reclaimed and Unmined Land, Battle River
Area, Alberta - Preliminary Results.
A. Howard. Alberta Research Council.
- 1520 Research Assessing the Reconstruction of
Soils Disturbed by Surface Mined Coal In
East - Central Alberta. A.L. Reid,
L.A. Leskiw. Pedology Consultants.
- 1540 Reclamation Activities by Crows Nest
Resources Limited In Alberta.
E.W. Fabro, D.K. Kittleson. Crows Nest
Resources Ltd.
- 1600 Evaluation of Bottom Ash as a Barrier to
Salt Movement from Sodic Mine Spoil.
C. Palmer. Alberta Environment.
- 1620 Closing Remarks - P. Zienkiewicz, Acting
President, Alberta Chapter, Canadian
Land Reclamation Association.
- 1630 Adjournment

LIST OF PARTICIPANTS

Arne Aasen Alberta Environmental Centre	Bart Bolwyn Alberta Environmental Centre
T. A. B. Adamson Union Oil Company of Canada	Jeffrey Bondy Alberta Energy and Natural Resources
Marian F. Adair Reid Crowther and Partners Ltd.	Trudy Bondy Edmonton, AB
Keith Ainsley Alberta Energy and Natural Resources	Connie Gay Boyce Western Oilfield Environmental Services
J. H. Allan Pisces Environmental Consulting Services	D. L. Bratton Alberta Environment
Earl T. Anderson Syncrude Canada Ltd.	Terryann Broadhurst Amoco Canada Petroleum Co. Ltd.
Robyn Andries University of Alberta	Larry Brocke Alberta Environment
Al Andrychuk Stanley - IEC	Bruce D. Cairns Alberta Energy and Natural Resources
Ted Angen Western Reclamation Services	L. T. L. Callow Gulf Canada Resources Inc.
Terry Aronyk Edmonton Power	James A. Campbell Alberta Environment
E. A. (Ken) Babcock Alberta Research Council	Karen R. Cannon University of Alberta
Don Bacon TransAlta Utilities Corporation	Fred Cartwright Shell Canada Resources Ltd.
Doug Badke Burnco Rock Products Ltd.	David Chanasyk University of Alberta
W. J. Bauer County of Stettler #6	Ray Chopiuk Coal Mining Research Centre
Doug Beddome Alberta Environment	Hans E. Christensen Alberta Environment
Roger K. M. Bellows Alberta Power Limited	Chin B. Chu Alberta Environmental Centre
Vernon Betts Smoky River Coal Ltd.	

Neil Chymko
Alberta Environment

Tom J. Cloutier
Fording Coal

W. L. Cody
Alberta Agriculture

Paul L. Coleman
PanCanadian Petroleum Ltd.

Brian Colgan
Alberta Agriculture

Les Collins
Alberta Utilities and
Telecommunications

Ken Crane
Luscar Ltd.

Jean Crepin
Norwest Soil Research Ltd.

Don L. Dabbs
Dabbs Environmental Services

Tony S. Dai
Syncrude Canada Ltd.

R. M. Danielson
University of Calgary

Jim H. Decker
Manalta Coal Ltd.

Dale Doram
TransAlta Utilities Corporation

G. J. Douglas
Saskatchewan Power Corporation

M. J. Dudas
University of Alberta

Roger Dunlop
Kestrel Environmental Consulting
Ltd.

Mr. and Mrs. Roger Duquette
Surface Rights N.W. Saskatchewan

Doug Eckert
Redwater, AB

Ivor K. Edwards
Canadian Forestry Service

Hans Espe
Voyager Petroleums

Klaus E. Exner
NOVA, AN ALBERTA CORPORATION

Al W. Fedkenheuer
NOVA, AN ALBERTA CORPORATION

Rick Ferster
Luscar Ltd.

R. J. Fessenden
Alberta Research Council

W. G. Fisher
Alberta Environment

Joe Fitzpatrick
Vancouver, BC

Terry Forkheim
Norcen Energy Resources Ltd.

Andy Foulds
Burnco Rock Products Ltd.

Julia Fulford
Fording Coal Limited

Martin Fung
Syncrude Canada Ltd.

Harold Ganske
Alberta Forest Service

A. W. Geottel
Alberta Agriculture

Simonne Gerrie
IVHOA Associates

R. Gesshe
Olds College

Robert A. Gibbs
Butter Krebs Associates

Yvon Giouet Olds, AB	Dave Headdon Western Oilfield Environmental Services
Keith Grant Alberta Environment	Craig Heath Hardy Associates (1978) Ltd.
Lynn Graves-Reid Canadian Superior Oil Ltd.	John Hermans Alberta Agriculture
Roshan L. Grover Alberta Environment	James Hunt University of Alberta
J. C. Gunn Alberta Power Limited	W. B. Hutchison Whitecourt Mountain Seedling Nursery
Jim Hajash Brooks, AB	David Ingledew Prairie Seeds
R. R. Hansel Texaco Canada Resources Ltd.	R. P. Innes Hardy Associates (1978) Ltd.
D. Brook Harkor Alberta Agriculture	Rafique Islam Alberta Energy and Natural Resources
Chris Harris Husky Oil Operations Ltd.	Berny Jacob Olds, AB
Clarence Harrison Alberta Environment	Khalid Jamil Energy Resources Conservation Board
Bill Harron Western Soils Consulting Ltd.	J. W. Jansen Lorenzo Environmental Contractors Ltd.
Wayne Hart Petro-Canada	Duane Johnson Hardy Associates (1978) Ltd.
Jeff Hartley Alberta Energy and Natural Resources	Terry Johnson Alberta Environment
J. Hastie Hardy Associates (1978) Ltd.	Raymond Juska Lakeside Research
Cy Haukedal Esso Resources	John Jusypiwk County of Smoky Lake #13
Robert A. Hawes Norecol Environmental Consultants	J. A. Kayande Alberta Power Ltd.
Dana Hayden University of Alberta	John King Alberta Environment
Helen Heacock Dabbs Environmental Services	

Paul King
Alberta Forest Service

Wally King
Canadian Forestry Equipment

Dean Kittleson
Crows Nest Resources Ltd.

Len Knapik
Pedocan Land Evaluation Ltd.

Mr. and Mrs. Ernie Kneeland
Alberta Surface Rights Federation

Terry Kosinski
Alberta Fish and Wildlife Division

Les LaFleur
Luscar Ltd.

Nancy Laird
Crows Nest Resources Ltd.

S. Landsburg
Alberta Environment

Graham P. Latonas
Western Research

Sheila Leggett
Chevron Canada Resources Ltd.

Karen Le Gresley
Brian Dodds & Associates Ltd.

Leonard Leskiw
Pedology Consultants

George L. Lesko
Syncrude Canada Ltd.

Lee Lewis
Petro-Canada

Bart A. Lindsay
Texaco Canada Resources Ltd.

David Lloyd
Alberta Energy and Natural
Resources

Jiggy Lloyd
University of British Columbia

R. J. Logan
Luscar Ltd.

Phillip Lulman
TransAlta Utilities

Stuart Lunn
PanCanadian Petroleum Ltd.

Bill MacMillan
Alberta Research Council

Terry M. Macyk
Alberta Research Council

Raghubir Mangat
Alberta Recreation and Parks

Leon Marciak
Alberta Agriculture

R. T. Marvin
Alberta Energy and Natural
Resources

Al Mayer
Energy Resources Conservation
Board

L. D. McDonald
Texaco Canada Resources Ltd.

Walter McNary
Voyager Petroleums

Ron McNeil
Western Reclamation

Bruce McTavish
Reid Collins

Douglas A. Mead
Shell Canada Resources

Kyra Medlicott
University of Alberta

Michael A. Mensforth
University of Calgary

Kenneth Miklos
Norcen Energy and Resources Ltd.

Ron Millson
Alberta Fish and Wildlife

James Mitchell Foothills Pipeline	Chris Powter Alberta Environment
D. R. Mudry Techman Engineers Ltd.	Bill Price University of British Columbia
F. (Marlin) Murphy Gregg River Resources Ltd.	John Prostebby Edmonton Power
Anne Naeth University of Alberta	Holly Quan TransAlta Utilities
Todd Nash Edmonton, AB	John B. Railton TransAlta Utilities
R. Karen Natsukoshi Manalta Coal Ltd.	A. L. (Fred) Reid Pedology Consultants
Peter Nix E.V.S. Consultants Ltd.	Pat Reid Monenco Analytical Laboratories
Berend J. Nyhof Alberta Environment	Darlene Reynolds Golden West Seeds Ltd.
Bob Onciul Alberta Environment	James Robert Dome Petroleum Ltd.
Craig Palmer Alberta Environment	Darrel Roberts Interprovincial Pipe Line
Dave Paton NOVA, AN ALBERTA CORPORATION	Carla Roppel University of Alberta
Bruce Patterson Alberta Environment	Beverley Ross University of Alberta
Jim Popowich Fording Coal Limited	Malcolm K. Ross Crows Nest Resources Ltd.
Jim W. Pearson C.W. Reclamation Ltd.	Nicky Ross Chemex
Kjeld Pedersen County of Wheatland #16	Bill Russell Edmonton, AB
D. Peters Olds College	Mark A. Sahlstrom Terrasol Ltd.
Ross K. Pituka Alberta Environment	Eugene Saldanha Alberta Energy and Natural Resources
Patrick J. R. Porter Alberta Energy and Natural Resources	Alan R. Scheibner Western Oilfield Environmental Services

Raulph P. Schoeddert
Texaco Canada Resources Ltd.

W. R. (Bill) Schroeder
PFRA Tree Nursery, SK

Kelly Scott
Western Oilfield Environmental
Services

Robert Seager
NOVA, AN ALBERTA CORPORATION

Jack Shapansky
ESSO Resources

Michael Shea
Texaco Canada Resources Ltd.

Wade Shiplka
Edmonton, AB

Bruce Skirrow
Smoky River Coal Ltd.

Ann Slater
Monenco Consultants Ltd.

Ted Slusarczyk
Genesee Power Project Advisory
Committee

Anne Smith
Chemex

Edna Smith
Wainwright, AB

K. R. Smith
Alberta Environment

Victor N. Smith
Husky Oil Operations Ltd.

W. M. Smith
Alberta Environment

Ken Smulski
Area One Reclaiming

Norm Soder
Three Hills, AB

John Sorochan
Alberta Energy and Natural
Resources

R. C. Speer
Techman Engineers Ltd.

Richard B. Spencer
Norecol Consultants Ltd.

Rudy Spiess
Spiess Construction

G. Sterenberg
Alberta Research Council

Arie E. Struik
Alberta Environment

S. K. Takyi
Alberta Forest Service

A. R. Teal
Esso Resources Canada Ltd.

Ludwig Teichgraber
Calgary, AB

F. D. Terry
Alberta Environment

Stan Tracy
Alberta Environment

Darwin Trenholm
Overall Vegetation Management Ltd.

Mark R. Trudell
Alberta Research Council

Stephen Tuttle
Suncor Inc.

Al Twardy
Pedology Consultants

Dave Urso
Crows Nest Resources Ltd.

R. Valleau
Western Reclamation Services

Philip Venner
TransAlta Utilities

Suzanne Visser
University of Calgary

David Walker
Walker & Associates Ltd.

H. L. Walker
Alberta Forest Service

Ron Wallace
Petro-Canada

Steve Warner
Fording Coal Ltd.

Lynda E. Watson
Techman Engineers Ltd.

Calvin Webb
Environment Council of Alberta

G. R. Webster
University of Alberta

Bryne Weerstra
University of Calgary

John R. Wells
Alberta Environment

Ken Wells
Alberta Environment

Glen Werner
Alberta Agriculture

S. Richard White
Red Deer Regional Planning
Commission

Norm White
Unifarm

Hilary Wilkinson
Olds College

Brian Williams
Denca Construction Specialties Inc.

Lawrence D. Williams
Camrose, AB

Wayne Willis
Fort Collins, CO

Loren Winnick
Alberta Energy and Natural
Resources

Donald Wishart
Mutrie-Wishart Environmental
Consultants

Fred Wood
Western Reclamation Services

Leo E. Wurtz
Husky Oil Operations Ltd.

Don Young
Alberta Agriculture

Paul Ziemkiewicz
Alberta Energy and Natural
Resources

